

Argonne National Laboratory

PHYSICS DIVISION SUMMARY REPORT

April—September 1970

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PHYSICS DIVISION SUMMARY REPORT

April—September 1970

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FOREWORD

The Physics Summary is issued several times per year for the information of the members of the Division and a limited number of other persons interested in the progress of the work. It includes short reports on highlights of the current research, abstracts or short summaries of oral presentations at meetings, abstracts of papers recently accepted for publication, and publication notices of papers appearing in recent journals and books. Many of these reports cover work still in progress; the results and data they present are therefore preliminary, tentative, and often incomplete.

The research presented in any one issue of the Summary is only a small random sample of the work of the Physics Division. For a comprehensive overview, the reader is referred to the ANL Physics Division Annual Review issued each summer, the most recent being Argonne National Laboratory Report ANL-7728, which reports research in the year ending 31 March 1970.

The issuance of these reports is not intended to constitute publication in any sense of the word. Final results will be submitted for publication in regular professional journals or, in special cases, presented in ANL Topical Reports.

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I. RESEARCH HIGHLIGHTS

These research highlights are Physics Division contributions to the Physical Research Monthly Report which the Laboratory Director's Office sends to the Division of Research of the U. S. Atomic Energy Commission. They report interesting work that is currently in progress or that has just been completed.

ROTATIONAL BANDS OF ^{166}Ho

L. M. Bollinger and G. E. Thomas

Several years ago we initiated an important advance in neutron-capture γ -ray spectroscopy by showing that the average widths of high-energy radiative transitions can be determined accurately from a measurement of the γ -ray spectrum formed by the capture of neutrons in a band of energy that is broad enough to excite many resonances. These average widths are of interest in themselves, and in addition they may be used to determine the parities and to set narrow limits on the spins of the final states fed by the radiative transitions. Our study of the average-resonance-capture spectrum for the reaction $^{165}\text{Ho}(n, \gamma)^{166}\text{Ho}$ has now yielded an exceptionally complete body of data on nuclear states in ^{166}Ho and has demonstrated beyond question the power of the new experimental method.

The essence of the average-resonance-capture method is that the well-known random fluctuations in the intensities of high-energy radiative transitions from individual initial states are averaged out by summing the contributions from many resonances. The resulting γ -ray intensities depend only on general features of the (n, γ) reaction, the most important of which are the multipolarity of the radiative transition and the number of ways in which the final state can be fed. In the reaction of interest here, primary dipole transitions can populate

final states with spin $J = 2, 3, 4$, and 5 ; and the average intensities of the γ -ray lines allow one (as was discussed in ANL-7405, pp. 1—6, October—December 1967) to determine the parities of the final states and to choose between $J = 2$ or 5 and $J = 3$ or 4 . Our average-resonance-capture measurements carried out at the internal-target facility of the reactor CP-5 have revealed some 50 states in ^{166}Ho at excitation energies less than 830 keV . The parity is determined for all of these states and a limit on the spin is set for most of them. Many of the states had not been detected in the intensive investigations carried out previously by means of a variety of techniques.

A unique feature of an average-resonance-capture measurement is that it reveals all states of a given kind in a given range of energy, except for those missed because of failure to resolve individual γ -ray lines. As a consequence of this uniform sensitivity, we believe that we have detected all positive-parity states in ^{166}Ho with $J = 2, 3, 4$, or 5 at energies less than 850 keV , and this completeness in the data provides an unusual opportunity to develop a complete description of the band structure of the states. The analysis consists in a search for states of a given parity whose excitation energies E_J form sequences of states with energies at

$$E_J = E_0 + \beta J(J + 1)$$

and whose γ -ray intensities are consistent with what is required by the spin J .

The analysis of the ^{166}Ho data turns out to be surprisingly easy and, as is shown in Fig. 1, all 32 of the positive-parity states detected below 850 keV can be fitted into rotational bands that have reasonable characteristics. Similar bands are constructed for the negative-parity states. Altogether, the measurements reveal 17 rotational bands (8 of which had been identified previously), giving perhaps the largest number of bands reported yet for any single nuclide.

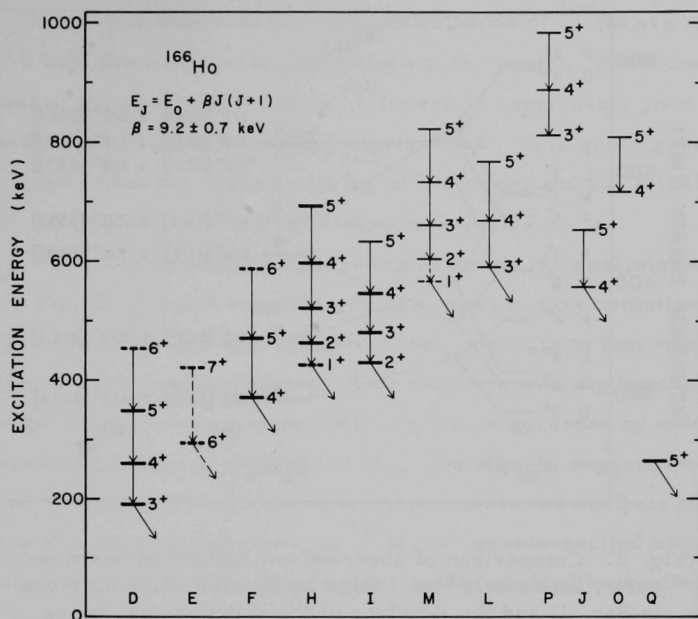


Fig. 1. Positive-parity rotational bands of ^{166}Ho . The states represented by heavy lines were observed and identified previously by Motz *et al.* (Ref. 1); the states represented by dashed lines are not populated by primary (n, γ) transitions. The connecting vertical arrows represent γ rays reported previously, and the diagonal arrows identify states from which relatively strong transitions are observed. The letters at the bottom are the band labels used in Fig. 2.

Additional information about the rotational bands of ^{166}Ho can be obtained by checking to see whether the γ rays that should connect the various members of each band were observed in the low-energy γ -ray spectra reported previously by Motz *et al.*¹ In all cases but one, there is a γ ray of the appropriate energy. This consistency between the energies of the states observed in our work and the low-energy γ -ray lines observed in earlier work tends to confirm the validity of the band structure.

¹ H. T. Motz *et al.*, Phys. Rev. **155**, 1265 (1967).

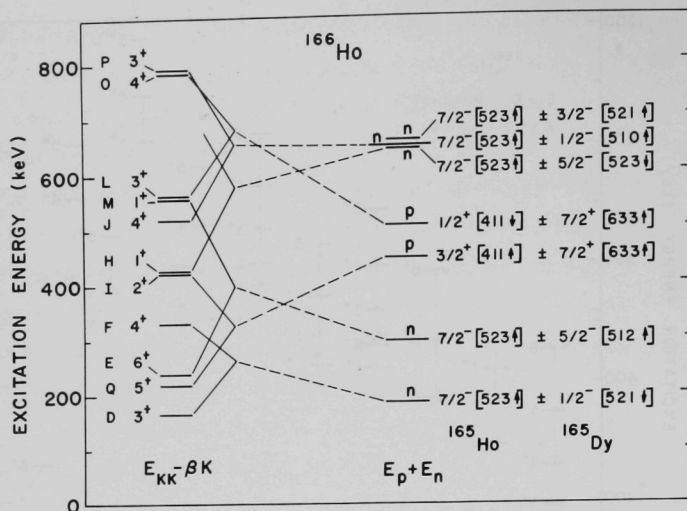


Fig. 2. Comparison of observed and predicted positive-parity bands in ^{166}Ho . Band labels (the same as those in Fig. 1) and the K values of the experimental bands are given on the left. The configurations of the intrinsic states in ^{165}Ho and ^{165}Dy that combine to form states in ^{166}Ho are given on the right. The letters n and p identify states that result from neutron-excited and proton-excited intrinsic states, respectively. The correspondence between the observed and predicted bands is shown by the dashed connecting lines.

The states in ^{166}Ho (a deformed odd-odd nucleus) may be interpreted in terms of a model in which the odd neutron and odd proton are independently coupled to a ^{164}Dy core. Then the intrinsic states of the odd neutron and odd proton may be determined from the known states of ^{165}Ho and ^{165}Dy , and these intrinsic states may be combined to form rotational bands in ^{166}Ho ; the energies of the band heads are (in rough approximation) equal to the sum ($E_p + E_n$) of the energies of the proton-excited and neutron-excited intrinsic states, and the spins K of the band heads are related to the spins Ω_p and Ω_n of the intrinsic states by $K = |\Omega_p \pm \Omega_n|$.

The observed positive-parity bands of ^{166}Ho are compared in Fig. 2 with the first-order predictions of the model. Here one sees that most of the observed bands in ^{166}Ho are in remarkably good agreement with these simple theoretical expectations. This good agreement seems to establish the overall validity of the model and again tends to confirm the reliability of our band-structure analysis.

One especially interesting aspect of the analysis summarized by Fig. 2 is that it suggests strongly that primary radiative transitions proceed with approximately equal strength to both neutron-excited and proton-excited states. This conflicts with the hypothesis that the (n, γ) reaction is a direct process that is governed by selection rules similar to those governing the (d, p) reaction—a suggestion advanced by Sheline, Motz, and associates. Since the analysis of Fig. 2 indicates that some of the states in ^{166}Ho are proton-excited states and since all of the radiative transitions of a given kind have effectively equal strength, our data strongly support the idea that the widths of high-energy radiative transitions are very insensitive to the nuclear structure of the final state.

RESONANCE IN THE M1 RADIATIVE STRENGTH IN ^{53}Cr

H. E. Jackson

The recently completed Argonne threshold photoneutron facility has been employed in a study of the $^{53}\text{Cr}(\gamma, n)^{52}\text{Cr}$ reaction. An intense p-wave structure observed in the photoneutron spectrum suggests strong M1 radiative transitions, and an analysis of the resonance yields indicates that the integrated intensity of magnetic-dipole transitions is very much stronger than the corresponding intensity for electric-dipole transitions.

One important effect of nuclear structure on radiation from highly excited states of nuclei is an enhancement of the strength of radiative transitions for specific nuclei containing single-particle excitations of a particular character and energy. For M1 transitions, these excitations are those generated by "spin-flip" transitions between the subshells of a given shell-model orbital split by spin-orbit coupling, viz. $(g_{9/2})^{-1}(g_{7/2})$. Experimental evidence for the existence of very intense M1 transitions has been observed in the mass region near $A = 120$ in studies of neutron-capture spectra of the tin isotopes and in the region near $A = 208$ in threshold photoneutron studies of the lead isotopes. Both cases correspond to mass regions near closed nucleon shells in which one subshell of a shell-model orbital is full and one empty. The enhancement of radiative strength can be attributed to dominance of transitions between the subshells. The threshold photoneutron measurements described here give evidence for strong magnetic-dipole transitions in ^{53}Cr . The latter contains one neutron outside the closed shell at $N = 28$ and the M1 strength can be explained by a strong 2-quasiparticle $(f_{7/2})^{-1}(f_{5/2})$ component in the states studied.

Measurements were performed on the Argonne threshold photoneutron facility at the high-current electron linac. A target of ^{53}Cr was irradiated by a pulsed bremsstrahlung beam with the end-point energy adjusted so that the nuclear states excited by photon

absorption can decay by neutron emission only to the ground state of ^{52}Cr . Neutron resonance groups corresponding to each of the states excited were observed by time-of-flight measurements, with the detector set to observe neutrons emitted at 90° and 135° relative to the photon beam. Data taken at 135° are shown in Fig. 3. Observed resonance energies agree very well with those calculated from the total neutron-capture cross section of ^{52}Cr .

The s-wave resonances in the (γ, n) spectra were located from the total neutron cross sections of ^{52}Cr , and data for 90° and 135° were normalized so that the relative yields gave isotropy for s-wave resonances. The ratio of the 90° to the 135° yield was then calculated for all other neutron groups. The results are listed in Table I. The spin assignments shown are based on the observed intensity ratio, which is expected to be $I(90^\circ)/I(135^\circ) = 1.0, 0.73, \text{ and } 1.33$ for total angular momenta $\frac{1}{2}, \frac{3}{2}, \text{ and } \frac{5}{2}$, respectively. The fact that no values corresponding to $j = \frac{5}{2}$ were observed indicates that there is no d-wave neutron emission in the region studied. Table I lists the known s-wave levels; the remainder must therefore correspond to p-wave neutron emission. The ground-state radiation widths in $^{53}\text{Cr}(\gamma, n)$ were determined by comparing the observed yields at 135° with the 135° yield observed for the resonance in Pb at 40.4 keV, for which the width is accurately known.

The central feature of the results is the exceptional strength of the p-wave resonances, which dominate the photoneutron spectrum. These resonances are excited by the absorption of magnetic-dipole and possibly electric-quadrupole radiation. In the analysis here, all the strength was presumed to be magnetic dipole. The observed total strength of transitions to p-wave states was 4.7 eV, corresponding to 0.4 Weisskopf units. The reduced matrix element for resonances with $J = \frac{1}{2}$ is $\bar{k}(M1) = 20_{-6}^{+15} \times 10^{-3}$ and for $J = \frac{3}{2}$ it is $\bar{k}(M1) = 7.0_{-1.6}^{+3.6} \times 10^{-3}$. A comparison with the known values for other nuclei indicates that the M1 strength for states in ^{53}Cr is comparable to the mean value

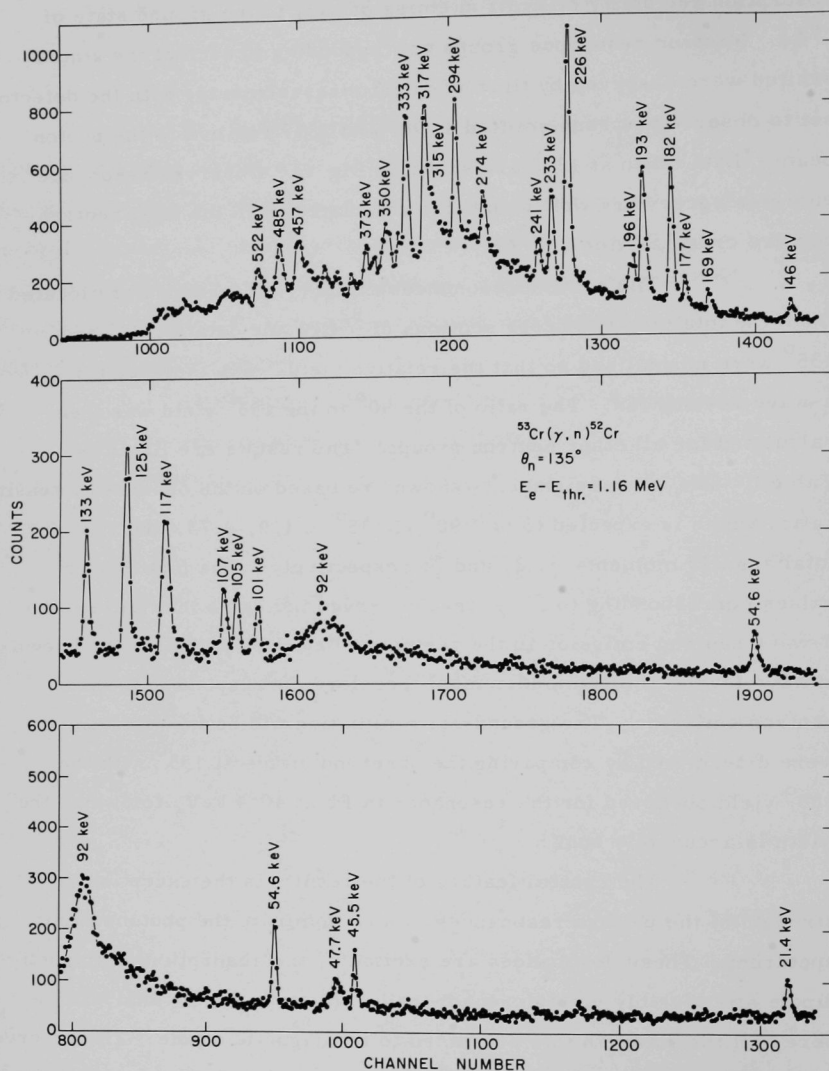


Fig. 3. Threshold photoneutron spectra for ^{53}Cr . Resonances are labeled by the observed photoneutron energy. The detection efficiency peaks near 250 keV because the detecting reaction $^6\text{Li}(n, \alpha)\text{T}$ has a resonance at 255 keV. The end-point energy E_e of the incident bremsstrahlung beam was 9.10 MeV.

TABLE I. Angular-momentum assignments for resonances in the reaction $^{53}\text{Cr}(\gamma, n)$.

E_n (keV)	$\frac{d\sigma(90^\circ)/d\Omega}{d\sigma(135^\circ)/d\Omega}$	J	E_n (keV)	$\frac{d\sigma(90^\circ)/d\Omega}{d\sigma(135^\circ)/d\Omega}$	J
0.373	1.06 ± 0.11	$\frac{1}{2}$	0.169	0.94 ± 0.11	. . .
0.350	0.68 ± 0.06	$\frac{3}{2}$	0.146	1.01 ± 0.10	$\frac{1}{2}$
0.333	1.01 ± 0.04	$\frac{1}{2}$	0.133	0.66 ± 0.04	$\frac{3}{2}$
0.317	0.71 ± 0.03	$\frac{3}{2}$	0.125	0.53 ± 0.03	$\frac{3}{2}$
0.315	s-wave	$\frac{1}{2}^+$	0.117	s-wave	$\frac{1}{2}^+$
0.294	1.09 ± 0.04	$\frac{1}{2}$	0.107	0.70 ± 0.06	$\frac{3}{2}$
0.274	0.66 ± 0.07	$\frac{3}{2}$	0.105	0.69 ± 0.06	$\frac{3}{2}$
0.241	0.72 ± 0.08	$\frac{3}{2}$	0.101	0.54 ± 0.06	$\frac{3}{2}$
0.233	1.10 ± 0.06	$\frac{1}{2}$	0.092	s-wave	$\frac{1}{2}^+$
0.226	s-wave	$\frac{1}{2}^+$	0.0546	0.88 ± 0.08	. . .
0.196	0.78 ± 0.08	$\frac{3}{2}$	0.0477	s-wave	$\frac{1}{2}^+$
0.193	1.10 ± 0.03	$\frac{1}{2}$	0.0455	0.56 ± 0.15	. . .
0.182	1.15 ± 0.03	$\frac{1}{2}$	0.0214	1.02 ± 0.12	. . .
0.177	0.89 ± 0.10	. . .			

$\bar{k}(M1) = 20 \times 10^{-3}$ of the reduced width for most nuclei that have been studied. In contrast to this, the reduced width $\bar{k}(E1)$ for electric-dipole transitions in ^{53}Cr is observed to be $1.1^{+0.44}_{-0.24} \times 10^{-3}$, much less than the average value 3.0×10^{-3} observed for a broad class of nuclei.

The shell-model configuration of the ground state of ^{53}Cr suggests a simple mechanism for enhancement of M1 radiation. Calculations indicate the existence of the appropriate two-quasi-particle excitation at just the energy necessary to account for the observed enhancement, namely a $(1f_{7/2})^{-1}(1f_{5/2})^{+1}$ particle-hole excitation. A large admixture of this excitation in the $\frac{1}{2}^+$ and $\frac{3}{2}^+$ states excited in $^{53}\text{Cr}(\gamma, n)$ would couple to the ground state of ^{53}Cr through the $f_{5/2} \rightarrow f_{7/2}$ spin-flip neutron transition and result in a strong enhancement of the M1 strength. If this explanation is correct, one can expect additional evidence for M1 enhancement in other nuclei near the $N = 28$ neutron shell.

OPERATION AND USE OF THE DYNAMITRON

R. L. Amrein, A. Langsdorf, Jr., F. P. Mooring, W. G. Stoppenhagen,
and J. R. Wallace

Since the last report on the 4-MV Dynamitron, requests for experimental time at the machine have greatly increased and indications are that its popularity as a research facility will continue to grow. Except for a few weeks during which a pulsed ion-source system was installed and tested, the Dynamitron has been used almost continuously since January 1970. Two ion-source systems, each with its own unique properties, are now being used and a third will become available in the near future.

The Dynamitron accelerator was equipped with a "Dynamag" ion source when delivered. With this source it is capable of delivering a wide range of dc beams (from 10^{-12} to 10^{-3} A). A principal area of research pursued at the Dynamitron facility is neutron physics. It is its ability to produce intense ion beams that qualify this accelerator as an excellent source of energetic neutrons.

In many experiments it is essential to measure the energies of neutrons produced in nuclear reactions. One can do this by determining the velocities of the neutrons by time-of-flight measurements. To do so it is essential to have the beam from the accelerator concentrated into short bursts. To accomplish this a pulsed ion-source system, purchased from ORTEC, was installed in the terminal of the Dynamitron during the winter. The beam-pulsing system, shown schematically in Fig. 4, consists of three basic parts—namely a conventional duoplasmatron ion source followed by a beam pulser and finally by a beam buncher. The beam from the source passes through a gridded lens which focuses it on a plate at the end of the beam pulser. This dc beam is swept up and down along a line slightly to one side of a small hole, which is at the center of the metal plate, at a sweep frequency of 2 MHz. Periodically the beam is deflected sideways and

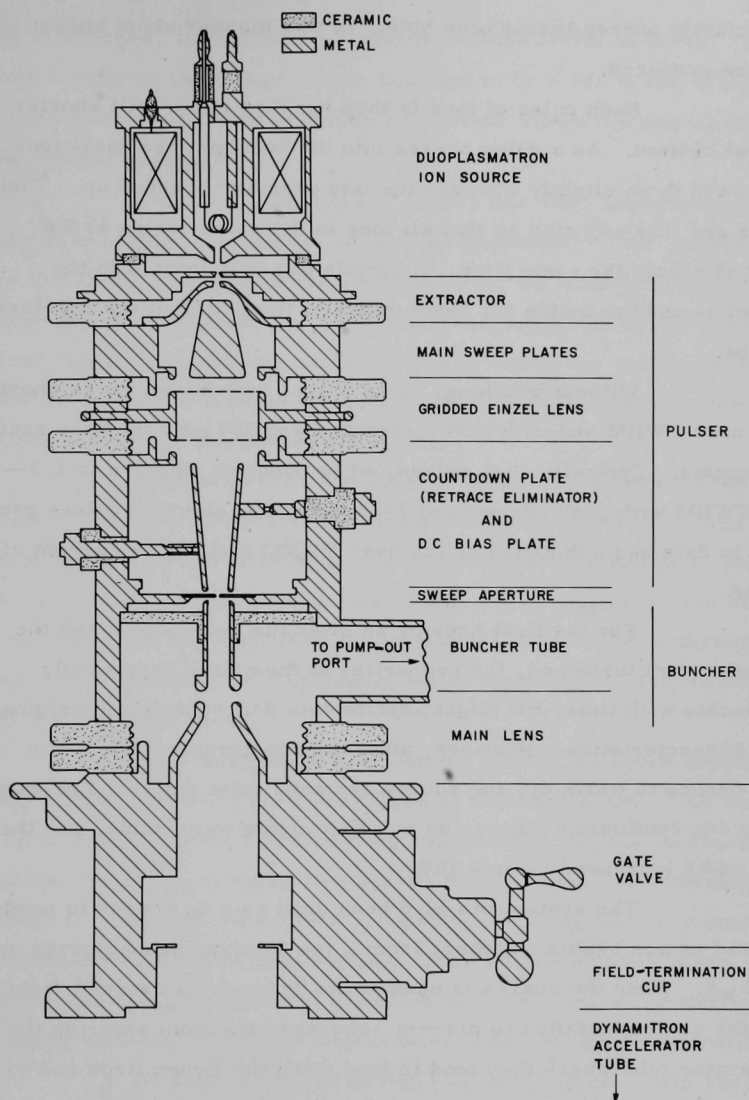


Fig. 4. Schematic diagram of the beam-pulsing system. The system consists of a conventional duoplasmatron which injects a beam into a pulsing system followed by a beam buncher. Where possible, the original ion-source electronics have been retained.

momentarily passes through the hole. In this manner short bursts of ions are produced.

Each pulse of ions is then bunched into a still shorter interval of time. As a pulse passes into the buncher, the early ions are slowed down slightly whereas the late ones are speeded up. Their speeds are thus adjusted so that all ions in the pulse arrive at the target at nearly the same time. A simple gap lens located in the buncher is used to match the beam optics to the optics of the accelerator tube.

Without bunching, beam pulses with durations as short as 14 nsec FWHM and with peak currents up to 800 μ A have been readily accelerated. Typically such pulses, when bunched, shorten to 1.3–1.5 nsec FWHM with peak currents of 2–3 mA. The shortest pulses produced to date had a duration of 1.0 nsec FWHM and a peak current of 1.6 mA.

For the first hour or so after the Dynamitron and the ion source are turned on, the properties of the pulses may slowly deteriorate with time, but slight adjustments will restore the original pulse characteristics. However, after the accelerator system has had a chance to warm up, the source becomes quite stable. For example, during one continuous 8-hour run no adjustments were made, and the pulse width increased by only 10%.

The system has also been used as a dc source to produce resolved proton beams anywhere from a few hundred nanoamperes up to 200 μ A. When the source is used in the dc mode, a crossed-field analyzer can be installed to prevent unwanted ions from entering the accelerator tube where they tend to load down the Dynamitron and to produce undesirable high radiation fields.

The focal properties of the new ion source are somewhat inferior to those of the Dynamag ion source. In both the pulsed and the dc mode, the spot size and the divergence of the beam are from three to five times those obtained with the Dynamag ion source. When the

beam is bunched, its quality worsens by another factor of three. This behavior reflects the compromises that had to be made in the beam optics to achieve optimum bunching properties within the spatial limitations of the terminal.

To date the pulsed ion source has been used mostly in a series of experiments designed to test the properties of the source itself and of the electronics used in measuring the time-of-flight of neutron groups. However, a preliminary measurement of the yields of neutron energy groups from analog states in nuclei has shown an energy dependence that was completely unexpected. These measurements will be continued in the immediate future.

Figure 5 shows the present layout of the Dynamitron facility. The Dynamitron itself is housed in a shielded vault. The emerging beam is deflected by a switching magnet into one of 13 possible beam lines. When hydrogen ions are used, the energy of the ion beam can be measured and controlled by passing the mass-2 beam through either of two electrostatic analyzers, while the proton (mass-1) beam is used in an experiment.

At present sixteen scientists working in seven experimental groups are using the Dynamitron in their research. The study of crystalline structure by channeling and blocking and the measurements of nuclear lifetimes by using Doppler-shift techniques are continuing. In addition, programs to explore properties of analog states in nuclei and nuclear fission have been started. Staff members from other divisions have begun studies of radiation damage, tritium production in reactor materials, and the effects of neutrons on cancerous cells.

During the course of these investigations, beam currents from 10^{-12} to 2×10^{-4} A have been used. With the lowest intensity, using the Dynamag ion source, extremely parallel ion beams have been obtained; the divergence (only 0.004°) is so small that the beam diameter would have grown only to $4\frac{1}{4}$ in. at one mile. With high beam

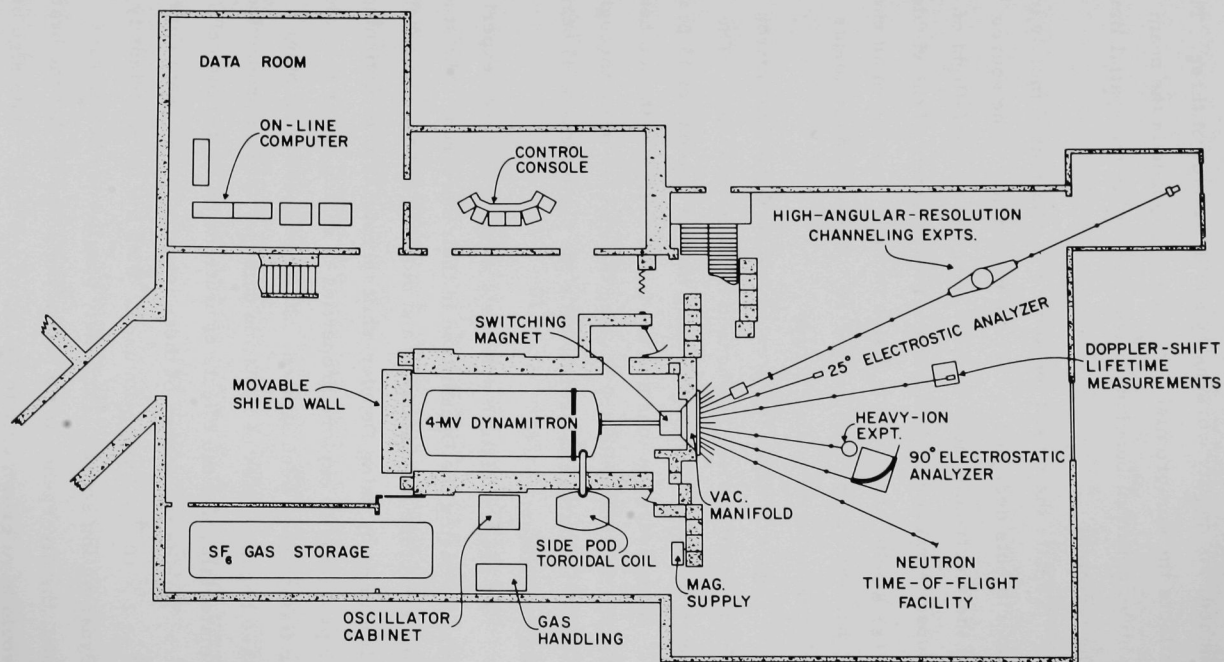


Fig. 5. Experimental lay-out of the Dynamitron facility. The major experimental set-ups are designated in the figure.

currents, the ${}^7\text{Li}(p,n){}^7\text{Be}$ reaction has been used to produce source strengths in excess of 10^{11} neutrons/sec.

The forthcoming installation of an ion source which will produce beams of heavy metallic ions will further enhance the versatility of an already unique experimental facility.

PAIR CORRELATIONS IN EXCITED 0^+ STATES OF ACTINIDE NUCLEI: A NEW COLLECTIVE MODE?

J. V. Maher, J. R. Erskine, A. M. Friedman,^{*}
J. P. Schiffer, and R. H. Siemssen

A surprising result has been found for excited 0^+ states observed with (p,t) reactions on actinide targets. In all six nuclides studied, the yield of the excited 0^+ state (near 900 keV excitation) is unusually large and is a nearly constant fraction ($\sim 15\%$) of the ground-state strength. In the (p,t) reaction the incident protons selectively pick up pairs of neutrons that have their spins opposite each other and that are strongly correlated, i. e., localized as a pair. In most nuclei with an even number of protons and neutrons it is found that this reaction selects the ground state, with all excited states at least a factor of 50—100 weaker. This is understood in terms of the dominant role of the pairing force in the nuclear ground state. The few cases in which excited states have been seen to be strongly populated in the (p,t) reaction are in regions of the periodic table where rapid changes occur either in the shell structure (pairing vibrations) or in nuclear deformation. The present results persist over a sufficiently large region of nuclei (^{228}Th , $^{232,234,236}\text{U}$, and $^{240,242}\text{Pu}$) to preclude an explanation in terms of a rapid transition in nuclear structure.

The reactions were studied with the 17-MeV proton beam from the Argonne tandem Van de Graaff accelerator. Tritons were detected with nuclear emulsions placed in the focal plane of the Enge split-pole spectrograph. An automatic nuclear-emulsion scanner was used to analyze the data. One of the spectra is shown in Fig. 6.

Angular distributions obtained for each target were sufficient to establish the sharp minimum at $\sim 35^\circ$, a characteristic of $l=0$ transitions. The most complete data were obtained for the $^{238}\text{U}(p,t)^{236}\text{U}$ reaction, for which the angular distributions are displayed

^{*} Chemistry Division.

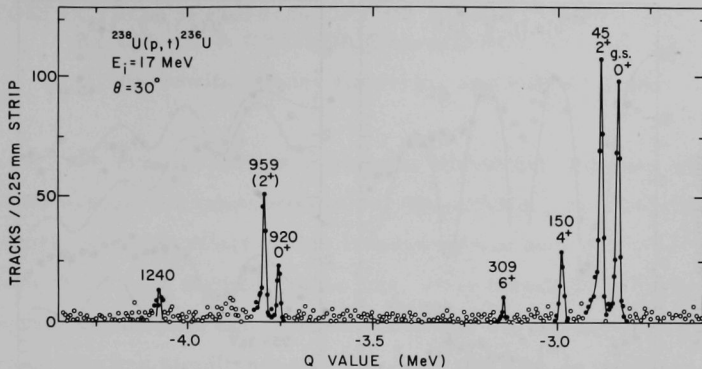


Fig. 6. Spectrum of tritons from the $^{238}\text{U}(p,t)^{236}\text{U}$ reaction. The target was $35 \mu\text{g}/\text{cm}^2$ of ^{238}U evaporated onto a carbon foil. The peaks are labeled with the excitation energies (keV) and spins of the corresponding states in ^{236}U .

in Fig. 7, along with DWBA calculations. The DWBA calculations fit the data especially well for the $\ell=0$ transitions. All 0^+ state assignments were made on the basis of our angular-distribution data.

Excited 0^+ states, and rotational bands based on them, have been long known in several of these nuclei. They have been characterized as β vibrations, though they are not connected to the ground state by quadrupole gamma-ray transitions as strong as would be expected for such a collective shape vibration. In ^{234}U , for which careful one-nucleon-transfer work has been done elsewhere with both the $^{235}\text{U}(d,t)$ and $^{233}\text{U}(d,p)$ reactions, no sign of this excited 0^+ band was seen. These bands show two additional previously known characteristics. (a) They exhibit electric monopole decays, an unusual feature, between members of the $K=0$ rotational band and the corresponding members of the ground-state band. (b) Strong alpha-particle decays (hindered only by factors of ~ 7 relative to the ground state) have also been observed to these excited 0^+ states in the few cases in which alpha decay is possible. This latter property may well be related to the enhancement we see for these states in the (p,t) reaction.

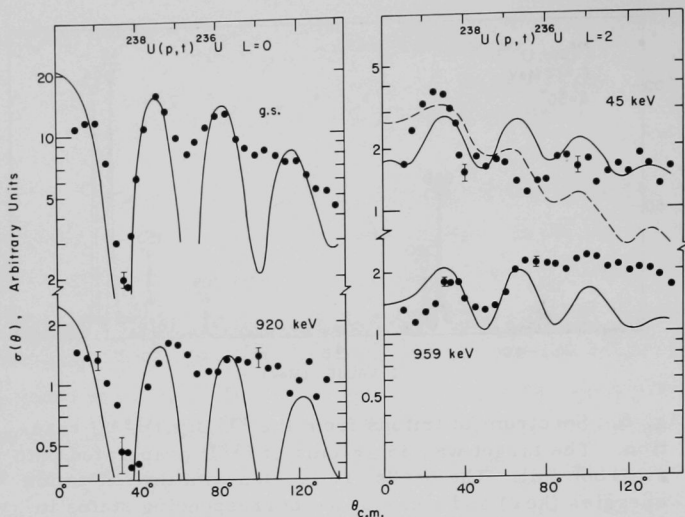


Fig. 7. Angular distributions for the $^{238}\text{U}(p,t)^{236}\text{U}$ reaction. Each data set is labeled with the excitation energy and the angular momentum transferred. The DWBA curves were calculated with a spherical $3d_{5/2}$ form factor for the solid curves and $1j_{15/2}$ for the dashed curve. Relative error bars are shown on a few representative points.

The interesting and surprising result of this study is that the population of the first 0^+ excited state is approximately the same for all these actinide targets. Taken together, the properties of these 0^+ states—namely the rather weak quadrupole transitions to the ground state, the monopole transitions, and our large values for the (p,t) cross sections—are not consistent with the expected properties of either β vibrations or pairing vibrations. All the evidence suggests that this type of 0^+ state is a simple and rather stable collective mode, closely related to the ground state and not readily explained within the current framework of collective excitations.

PHOTOELECTRON SPECTROSCOPY OF HIGH-TEMPERATURE VAPORS
BY USE OF A CYLINDRICAL-MIRROR ANALYZER

J. Berkowitz, Henry Halperin, and Reimar Spohr

The interaction of vacuum ultraviolet radiation with gases and vapors can cause excitation, dissociation, and ionization. Heretofore, a major effort in this laboratory has been directed toward the study of the ions formed in this way, their threshold behavior, and the general dependence upon the wavelength of the incident light. The electrons that are simultaneously liberated can also be analyzed for kinetic energy, and for this purpose an electron-energy analyzer of greatly improved sensitivity has been designed and put into operation at Argonne. Initial measurements indicate that this analyzer will enable us to study many additional molecular species and to extend the useful ranges of wavelengths.

If the wavelength of the light incident on atom or molecule is fixed, the kinetic energy of the electrons ejected is directly related to the quantum states of the ion formed in the interaction (via conservation of energy). Hence, a study of the photoelectron spectrum of a molecular species enables one to deduce the various accessible ionic states of the system and, by Koopman's theorem, the various ionization potentials of the molecule.

A large body of photoelectron spectroscopic data has been assembled in the past eight years by other laboratories, primarily using the helium resonance line as incident radiation and permanent gases as samples to be investigated. The reasons for, and the limitations of, this approach are obvious. With a resonance line as a light source, one does not require a vacuum ultraviolet monochromator with its attendant loss of intensity, and most of the energy going into the light source (usually a dc discharge lamp) is pumped into the resonance line. Hence, large light fluxes of monochromatic radiation can be achieved. Permanent gases can be conveniently introduced into the

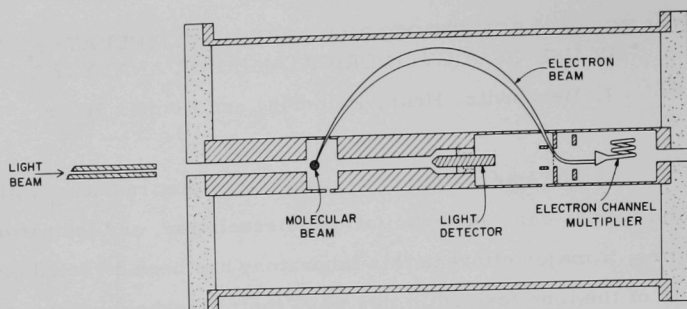
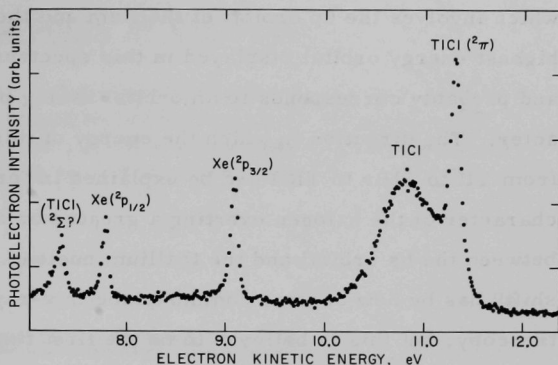


Fig. 8. Schematic diagram of the cylindrical-mirror electron-energy analyzer.

scattering region at the desired pressure; but nonvolatile or unstable molecular species must be generated in a molecular beam. Since the effective molecular density in such a beam is significantly lower than that in an ambient gas, the result again is a weaker signal.

To compensate for these losses of intensity and thus to make other molecular systems and other wavelengths accessible to study, we have constructed an energy analyzer that has a large acceptance angle and does not sacrifice resolution. As shown in Fig. 8, it consists of two concentric cylinders. The inner cylinder has circular entrance and exit slits. In the present mode of operation, a beam of photons is directed along the common axis of the cylinders. A molecular beam (of permanent gas, nonvolatile vapor, or unstable species) is directed along a diameter of the cylinders and intersects the photon beam at the axis. The photoelectrons generated in the interaction region are ejected in a full 4π solid angle, but those finding their way through the circular entrance slit of the inner cylinder enter a region of logarithmic potential maintained between the cylinders. If these electrons have the proper energy and angle, they will describe a trajectory which takes them back through the exit slit and into the central region where they strike a channeltron multiplier and are counted as pulses. By varying the potential between the cylinders to

Fig. 9. Photoelectron spectrum of TlCl , obtained with the 584 Å resonance line of helium. The measurement was made with the new cylindrical-mirror analyzer, and xenon was introduced as a calibrating gas.



scan the range of electron energies and simultaneously advancing a multichannel analyzer, one can obtain a photoelectron spectrum directly.

Preliminary experiments with this apparatus have demonstrated that with 1-mm entrance and exit slits, it has a resolving power of ~ 40 meV for electrons of ~ 6 eV energy and that the intensity at peaks is $\sim 2 \times 10^4$ electrons/sec. Higher resolution should be possible with narrower slits. For many high-temperature systems the natural broadening caused by the Boltzmann distribution makes higher resolution unnecessary.

One of the first results obtained with a high-temperature molecular beam is shown in Fig. 9. Three peaks attributable to the molecule TlCl can be noted as well as two due to the gas xenon, which has its spin-orbit-split ionic states conveniently located to calibrate the energy scale. The first ionization potential of TlCl evidently corresponds to the ejection of an electron from a nonbonding orbital; the narrowness of this peak implies that the lowest-lying potential energy curve of TlCl^+ has about the same shape and internuclear distance as the neutral ground state. The electron ejected is conveniently described as a $p\pi$ electron predominantly localized on the chlorine atom. The next more energetic peak is much broader, and most probably involves ejection of an electron from the bonding $p\sigma$ orbital,

which involves the 6p orbital of thallium and the 3p of chlorine. The highest energy orbital displayed in this spectrum is also rather narrow, and probably corresponds to an orbital having predominantly 6s character. The direction in which the energy of this peak shifts in going from TlI to TlBr to TlCl can be explained in terms of the electronegative character of the halogen exerting a greater or lesser shielding effect between the 6s orbital and the thallium nucleus. This type of "chemical shift" has by now become commonplace in x-ray photoelectron spectroscopy, but this is believed to be the first time this interpretation could be applied to vacuum-ultraviolet photoelectron spectroscopy.

A careful analysis of the shapes of these peaks in TlCl and other systems analyzed more recently should make it possible not only to obtain accurate values for the various ionization potentials of each system, but also to deduce potential curves for the corresponding ionic states. A comparison of the results from photoionization and photoelectron spectroscopic investigations can provide insight into the details of molecular fragmentation, answering such questions as: Which orbital is primarily responsible for molecular binding?

II. REPORTS AT MEETINGS

The abstracts and summaries that follow are not necessarily identical to those submitted for the meeting. In some cases, the authors have corrected or expanded abstracts; and summaries of contributed papers commonly have been shortened.

American Physical Society

Washington, D. C., 27—30 April 1970

IDENTIFICATION OF PARTICLE-HOLE MULTIPLETS IN ^{88}Y

R. C. Bearse, J. R. Comfort, J. P. Schiffer, M. M. Stautberg,
and J. C. Stoltzfus

Bull. Am. Phys. Soc. 15, 574 (April 1970)

The reactions $^{88}\text{Sr}(^3\text{He}, t)^{88}\text{Y}$ and $^{87}\text{Sr}(^3\text{He}, d)^{88}\text{Y}$ have been investigated at bombarding energies of 23 and 18 MeV, respectively. Approximately 29 states are identified up to an excitation energy of 2.3 MeV. The angular distributions and intensities obtained from these and neutron pickup reactions on ^{89}Y allow us to suggest both J^π assignments and identifications of levels with members of expected particle-hole multiplets. The multiplets formed by $p_{1/2}$ and $g_{9/2}$ proton particles with $g_{9/2}$, $p_{1/2}$, $p_{3/2}$, and $f_{5/2}$ neutron holes do in fact result in 28 simple particle-hole states in this region of excitation energy.

STRUCTURE IN THE STRENGTH FUNCTION OF M1 TRANSITIONS IN $^{105}\text{Pd}(n, \gamma)^{106}\text{Pd}$

L. M. Bollinger and G. E. Thomas

Bull. Am. Phys. Soc. 15, 548 (April 1970)

An average-resonance-capture measurement for $^{105}\text{Pd}(n, \gamma)^{106}\text{Pd}$ gives accurate values for the average intensity of

M1 transitions at 15 energies throughout the range 6.78—9.05 MeV.

A plot of $\Gamma_{\gamma} E_{\gamma}^{-3}$ vs E_{γ} forms a smooth giant-resonance-like curve that has a maximum at 7.8 MeV and a width (FWHM) of roughly 2.5 MeV. This behavior is qualitatively similar to that calculated for heavy deformed nuclei by Shapiro and Emery.¹

¹ C. S. Shapiro and G. T. Emery, Phys. Rev. Letters 23, 244 (1969).

LEVEL SCHEME OF ¹⁸⁰Hf

D. L. Bushnell,* R. K. Smither, and D. J. Buss
Bull. Am. Phys. Soc. 15, 524 (April 1970)

Thermal neutron-capture gamma-ray data from the reaction ¹⁷⁹Hf(n, γ) ¹⁸⁰Hf is combined with average resonance neutron-capture gamma-ray data for the same reaction to obtain energies, spins, and parities of states in ¹⁸⁰Hf. An attempt is made to interpret the levels between 1 and 2 MeV as positive- and negative-parity rotational bands. The neutron binding energy for ¹⁸⁰Hf was found to be 7387.5 \pm 0.5.

* Northern Illinois University, DeKalb, Illinois.

PARTICLE-HOLE MULTIPLETS AND (d, α) REACTIONS IN THE A \approx 90 REGION

J. R. Comfort, J. V. Maher, G. C. Morrison, and H. T. Fortune

Bull. Am. Phys. Soc. 15, 574 (April 1970)

Angular distributions of the (d, α) reactions on ⁹⁰Zr, ⁹²Mo, and ⁹⁸Mo targets have been obtained with the Enge split-pole spectrograph and 17-MeV deuterons from the Argonne tandem. The targets were rolled foils of thickness 200—250 $\mu\text{g}/\text{cm}^2$. Particle-hole

multiplets in ^{88}Y , ^{90}Nb , and ^{96}Nb observed in the ($^3\text{He}, t$) reaction are also excited in the (d, α) reaction. However, the fact that the (d, α) reaction is prohibited from populating even-spin states of j^2 configurations makes possible a test of the purity of configuration assignments. For example, the 970-keV state of ^{88}Y , identified in the ($^3\text{He}, t$) reaction as the $J^\pi = 4^+$ member of the $(g_{9/2})^2$ multiplet, is unobserved in the (d, α) reaction.

MEAN LEVEL WIDTH AND ITS RATIO TO MEAN LEVEL SPACING IN HIGHLY EXCITED COMPOUND NUCLEI

K. A. Eberhard* and A. Richter†

Bull. Am. Phys. Soc. 15, 570 (April 1970)

The content of this paper is included in the more comprehensive report in ANL-7728, pp. 132—133.

* Florida State University, Tallahassee, Florida.

† On leave of absence from the Max-Planck-Institut für Kernphysik, Heidelberg, Germany.

ENERGY LEVELS IN ^{34}Cl FROM $^{33}\text{S}(^3\text{He}, d)^{34}\text{Cl}$

J. R. Erskine, D. Crozier, J. P. Schiffer, and W. P. Alford*

Bull. Am. Phys. Soc. 15, 484 (April 1970)

We have studied the above reaction, using the Enge split-pole magnetic spectrograph and the 14-MeV ^3He beam of the Argonne tandem Van de Graaff accelerator. The target was CdS enriched in ^{33}S to 83%. Angular distributions were obtained in 5° steps between 10° and 60° . The data cover states up to 5 MeV excitation energy with a resolution width of 15 keV. We hope to extract information on the $(d_{3/2} f_{7/2})$ multiplet.

* University of Rochester, Rochester, New York.

NUCLEAR STRUCTURE OF ^{20}F : THE $^{19}\text{F}(\text{d},\text{p})$ REACTIONH. T. Fortune,* R. C. Bearse,[†] G. C. Morrison, J. L. Yntema, and H. Wildenthal[‡]Bull. Am. Phys. Soc. 15, 483 (April 1970)

Using a magnetic spectrograph, the $^{19}\text{F}(\text{d},\text{p})^{20}\text{F}$ reaction has been studied at $E_{\text{d}} = 16.0$ MeV. At this energy, states having large cross sections are expected to be populated mainly via direct stripping. Of the previously-known 21 states below $E_{\text{x}} = 4.3$ MeV, angular distributions (at 14 angles) were obtained for all but three of them (at $E_{\text{x}} = 1.824$, 2.871, and 3.176 MeV). Strong stripping angular distributions were observed for ten states—six dominated by $\ell = 2$ and four by $\ell = 0$. These ten states agree reasonably well in position and strength with the ten lowest states predicted by recent shell-model calculations to have appreciable amounts of the configuration [$^{19}\text{F}(\text{g.s.}) \times (1\text{d}_{5/2}$ or $2\text{s}_{1/2}$ neutron)].

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SOME CALCULATED ANGULAR DISTRIBUTIONS FOR CHanneled IONS

D. S. Gemmell

Bull. Am. Phys. Soc. 15, 657 (April 1970)

The form of the average potential experienced by planar-channelled ions in monocrystals can make the wavelength of the ion oscillations strongly amplitude dependent. The resultant effects on the energy distribution for ions emerging from thin monocrystals have been observed.¹ Fine structure in the angular distributions is also

¹ H. O. Lutz et al., Phys. Rev. Letters 17, 285 (1966).

predicted.² The present computer calculations of the latter used a CDC-3600 for numerical integration of the classical equations of motion for channeled particles. After testing with an harmonic-oscillator potential, the calculations were run using Molière's approximation³ to the Thomas-Fermi potential. The fine structure depends on ion species, energy, thickness and characteristics of the crystal, etc. The results will be compared with measurements made at Argonne and at Heidelberg.²

² W. Dünnweber, Diplomarbeit, 1968; W. Dünnweber, D. Gemmell, H. Lutz, C. Mayer-Böricke, and M. Rogge, Jahresbericht 1968, Max-Planck-Institut für Kernphysik, Heidelberg.

³ C. Erginsoy, Phys. Rev. Letters 15, 360 (1965).

POLARIZATION AND DIFFERENTIAL CROSS SECTION FOR NEUTRONS SCATTERED FROM ¹⁰B

S. L. Hausladen,* R. O. Lane,* J. E. Monahan, A. J. Elwyn, F. P. Mooring, and A. Langsdorf, Jr.

Bull. Am. Phys. Soc. 15, 567 (April 1970)

Polarization $P(\theta)$ and differential cross section $\sigma(\theta)$

for the scattering of neutrons have been measured for 0.075 MeV $\leq E_n \leq 2.2$ MeV. Simultaneous fitting of $P(\theta)$ and $\sigma(\theta)$ via R-matrix parameters show that the anomaly in ¹¹B* at $E_x = 13.15$ MeV consists of two broad, nearly overlapping states formed by $\ell=1$ and $\ell=2$ neutrons. The previous single assignment of $J^\pi \geq \frac{11}{2}^+$ for this anomaly was inconsistent with these data. A state at $E_x = 11.94$ MeV ($E_{res} = 0.53$ MeV, $\Gamma_n \approx 0.013$ MeV, $\Gamma_a \approx 0.150$ MeV) is assigned $\frac{5}{2}^-$ ($\ell = 1$), nearly all channel spin $S = \frac{7}{2}$. The present integrated $\sigma(\theta)$ reveals clearly a very broad ($\gamma_n^2 \approx 0.6$ MeV, $\Gamma_a \approx 0.1$ MeV) s resonance (not previously known) at $E_{res} = 0.35$ MeV ($E_x = 11.78$ MeV), best fitted with $J^\pi = \frac{7}{2}^+$.

* Ohio University, Athens, Ohio.

It predicts the major part of the well-known large (n, α) cross section of $1/v$ form below $E_n = 0.1$ MeV. Contributions of other s states are being investigated.

PROTON SCATTERING ON ^{96}Zr THROUGH ISOBARIC ANALOG RESONANCES

R. R. Jones,* C. Fred Moore,* P. Dyer,[†] N. Williams,[‡]
and G. C. Morrison

Bull. Am. Phys. Soc. 15, 626 (April 1970)

Inelastic scattering of protons on ^{96}Zr has been measured on the prominent isobaric analog resonances in ^{97}Nb . Excitation functions for the $(0^+, 1.59 \text{ MeV})$, $(2^+, 1.73 \text{ MeV})$, and $(3^-, 1.90 \text{ MeV})$ have been determined as well as angular distributions on and off resonances. Spectroscopic information will be given. The parentage of possible configurations of several states will be discussed. For example, the $(0^+, 1.59 \text{ MeV})$ state shows no obvious weak-coupling resonance with the single-particle states; however, the $(3^-, 1.90 \text{ MeV})$ state displays the weak coupling to these single-particle states with prominent resonances at $E_p = 7.90 \text{ MeV}$ ($s_{1/2}$) and 9.15 MeV ($d_{3/2}$). This talk reports completion of earlier work.¹

* University of Texas, Austin, Texas.

[†] California Institute of Technology, Pasadena, California.

[‡] Rutgers University, New Brunswick, New Jersey.

¹R. R. Jones, P. Dyer, C. F. Moore, G. Morrison, and N. Williams, Bull. Am. Phys. Soc. 13, 562 (1968).

THE $^{24,26}\text{Mg}(p, \alpha)^{21,23}\text{Na}$ REACTIONS AT 35 MeV

E. Kashy,* W. Pickles,* G. C. Morrison, and R. C. Bearse
Bull. Am. Phys. Soc. 15, 544 (April 1970)

Angular distributions of the $^{24,26}\text{Mg}(p, \alpha)$ reactions, measured with 35-MeV protons from the MSU cyclotron, confirm that the (p, α) reaction at these energies is analogous to the direct $(d, ^3\text{He})$ reaction on an $(N - 2)$ target; proton-hole states are strongly populated. In the $^{24}\text{Mg}(p, \alpha)$ reaction, hole states of negative parity in ^{21}Na are observed at 2.81 (one member of a doublet) and 3.68 MeV. The j dependence of the (p, α) angular distribution fixes their spins and parities as $\frac{1}{2}^-$ and $\frac{3}{2}^-$, respectively, in agreement with theoretical expectations but contrary to a $\frac{3}{2}$ assignment for the mirror state of the lower at 2.79 MeV in ^{21}Ne . The $^{26}\text{Mg}(p, \alpha)$ reaction to the known negative-parity states in ^{23}Na confirms the j dependence. The relative strengths of the two reactions to corresponding states are very similar, although the ^{26}Mg cross sections are only $\frac{1}{5}$ of those of ^{24}Mg . Some reduction can be accounted for on the Nilsson model of these nuclei.

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$^{86}\text{Sr}(^3\text{He}, d)^{87}\text{Y}$ REACTION AT 20 MeV

J. V. Maher, J. R. Comfort, and G. C. Morrison
Bull. Am. Phys. Soc. 15, 551 (April 1970)

Angular distributions for the $^{86}\text{Sr}(^3\text{He}, d)^{87}\text{Y}$ reaction have been obtained with the Enge split-pole spectrograph and the 20-MeV ^3He beam from the Argonne tandem. ^{87}Y has not been extensively studied previously and is of particular interest because of the possible shell closure of the 38-proton configuration. States of strong excitation in ^{87}Y are observed at $E_x = 0.00$ ($\ell = 1$), 0.38 ($\ell = 4$), 0.79, 0.98, 1.15, 2.91, and 3.00 MeV. A DWBA analysis of the angular distributions is in progress.

ANGULAR DISTRIBUTION OF RADIATION FROM PROTON CAPTURE BY THE CHLORINE ISOTOPES

L. Meyer-Schützmeister, D. S. Gemmell, N. G. Puttaswamy, H. T. Fortune, J. V. Maher, E. L. Sprenkel-Segel, R. C. Bearse, and R. E. Segel

Bull. Am. Phys. Soc. 15, 566 (April 1970)

Proton capture by the chlorine isotopes offers an opportunity to study the isospin splitting of the giant resonance since the pure isovector nature of E1 radiation requires that the giant resonance in $T_z = 0$ ^{36}Ar [from $^{35}\text{Cl}(p, \gamma)$] should be pure $T = 1$, while that in $T_z = 1$ ^{38}Ar [from $^{37}\text{Cl}(p, \gamma)$] should have $T = 1$ and $T = 2$ components of roughly equal strength. Evidence for the T splitting has been reported¹ in the yield curves for $^{37}\text{Cl}(p, \gamma_0)$. The $^{35}\text{Cl}(p, \gamma_0)$ angular distributions show the constancy usually found in even-even $T_z = 0$ nuclei. For $^{37}\text{Cl}(p, \gamma_0)$ the variations in the angular distributions are also small, with a_2 slightly positive in the lower part of the giant-resonance region and slightly negative in the upper part.

¹R. E. Segel et al., Bull. Am. Phys. Soc. 15, 47 (1970).

$^{96}\text{Zr}(^3\text{He}, t)^{96}\text{Nb}$ REACTION AT 21 MeV

G. C. Morrison, J. R. Comfort, J. V. Maher, and J. P. Schiffer

Bull. Am. Phys. Soc. 15, 574 (April 1970)

Angular distributions of the $^{96}\text{Zr}(^3\text{He}, t)^{96}\text{Nb}$ reaction have been measured with the Enge split-pole spectrograph and a 21-MeV ^3He beam from the Argonne tandem Van de Graaff. Below an excitation energy of 2 MeV, six levels—corresponding to the expected $(d_{5/2}^{-1}n)(g_{9/2}p)$ multiplet—are strongly excited. Excitation energies (keV) and the tentative J^π assignments based on the associated angular distributions are: 0 (6^+), 43 (5^+), 152 (3^+), 191 (4^+), 233 (7^+), and 637 (2^+). States of $(g_{9/2})^2$ configuration are expected at higher excitation

energies. The $^{96}\text{Nb} (g_{9/2})_p (d_{5/2})_n^{-1}$ particle-hole spectrum is related by the Pandya transformation to the known $(g_{9/2})_p (d_{5/2})_n$ spectrum in ^{92}Nb . It is found that this transformation is satisfied remarkably well; the residual two-body interaction is found to be -372 ± 20 and $+369 \pm 20$ keV in ^{92}Nb and ^{96}Nb , respectively. These values result from the recently remeasured Q values of -308 keV for $^{90}\text{Zr}({}^3\text{He}, d){}^{91}\text{Nb}$ and 218 keV for $^{96}\text{Zr}({}^3\text{He}, t){}^{96}\text{Nb}$.

POLARIZATION AND DIFFERENTIAL CROSS SECTIONS FOR SCATTERING OF NEUTRONS FROM ^{11}B

C. E. Nelson,* R. O. Lane,* J. L. Adams,* J. E. Monahan,
A. J. Elwyn, F. P. Mooring, and A. Langsdorf, Jr.
Bull. Am. Phys. Soc. 15, 567 (April 1970)

The polarization $P(\theta)$ and differential cross section $\sigma(\theta)$ for the scattering of neutrons from ^{11}B have been measured for $0.075 \text{ MeV} \leq E_n \leq 2.2 \text{ MeV}$. Both $\sigma(\theta)$ and $P(\theta)$ are simultaneously fitted reasonably well by R-matrix parameters for broad states in ^{12}B with assignments 2^- ($\ell = 0$) and 4^- ($\ell = 2$), for excitation energies $E_x = 4.37 \text{ MeV}$ and 4.54 MeV , respectively. The 2^- level has not previously been seen, while the 4^- level has previously been assigned to be 3^- . These results together with a previous 3^- assignment for a broad state at $E_x = 3.39 \text{ MeV}$ give experimental evidence for previously unobserved proton-hole neutron-particle shell-model configurations $(1p_{3/2})^{-1}(1d_{5/2})$ and $(1p_{3/2})^{-1}(1s_{1/2})$ in ^{12}B . Shell-model calculations made with δ -function residual interactions including configuration mixing of resulting 2^- states were able (under certain assumptions) to predict these experimental results. Work on $T=1$ states in $^{12}\text{C}^*$ has been compared with the present work.

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HIGH-LYING NEUTRON-HOLE STATES POPULATED IN THE REACTION $^{13}\text{C}(\text{p},\text{d})^{12}\text{C}^*$ AT 63 MeV

L. J. Parish,* A. Brown,* K. A. Eberhard,* A. Richter,[†]
 and W. v. Witsch[‡]

Bull. Am. Phys. Soc. 15, 520 (April 1970)

The content of this paper is included in the more comprehensive report in ANL-7728, p. 97.

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THE $^{48}\text{Ca}(^3\text{He},\text{t})^{48}\text{Sc}$ REACTION AT 23 MeV

A. Richter,* J. R. Comfort, and J. P. Schiffer

Bull. Am. Phys. Soc. 15, 594 (April 1970)

The content of this paper is included in the more comprehensive report in ANL-7728, p. 65.

* On leave of absence from the Max-Planck-Institut für Kernphysik, Heidelberg, Germany.

VIBRATION AMPLITUDES IN THE MOLECULAR CRYSTAL $\text{Sn}(\text{CH}_3)_4$

S. L. Ruby, I. Pelah,* and J. E. Robinson*

Bull. Am. Phys. Soc. 15, 605 (April 1970)

By careful absolute measurement of the Mössbauer fraction f of $\text{Sn}(\text{CH}_3)_4$, $x^2(T)$ for the tin atom is obtained for $78^\circ\text{K} < T < 210^\circ\text{K}$. The results are quite poorly fitted by the simple Debye model and it is clearly necessary to allow for, at least, lattice expansion

* Solid State Science Division.

and/or anharmonicity. Forcing the data to yield an effective Debye temperature $\theta(T)$ gives values ranging downward from 70°K (at 90°K) by over 10% at higher temperature. The experimental results will be compared with the predictions of models using intermolecular LJ potentials.

EXCITED 0^{+} STATES IN THE (p,t) REACTION ON Pt, W, AND U ISOTOPES

J. P. Schiffer, J. V. Maher, J. R. Erskine, A. Friedman,*
and R. H. Siemssen

Bull. Am. Phys. Soc. 15, 528 (April 1970)

A report on this work, presented as a Research Highlight, appears on p. 16.

* Chemistry Division.

MEAN LIVES OF THE SECOND AND THIRD EXCITED STATES IN ^{40}K

R. E. Segel, N. G. Puttaswamy, N. Williams, G. H. Wedberg,
and G. B. Beard

Bull. Am. Phys. Soc. 15, 600-601 (April 1970)

It is tempting to describe the ground state and first three excited states in ^{40}K as the four states of the $(d_{3/2})^{-1}f_{7/2}$ quartet. In this case the three possible M1 transitions are simply related by factors involving only spin and energy. We have measured the lifetimes of the second and third excited states by use of the attenuated-Doppler-shift technique. The states were populated by the $^{39}\text{K}(d,p)$ reaction and the recoil direction was defined by coincidence with the outgoing proton. We found that $\tau_2 = (2 \pm 1) \times 10^{-12}$ sec for the second excited state and $\tau_3 = (4.5 \pm 1.5) \times 10^{-12}$ sec for the third; the expected ratio is $\tau_3/\tau_2 = 1.4$. These results are inconsistent with the measured

lifetime¹ of the first excited state in the simple particle-hole picture; the measured ratio τ_2/τ_1 is at least double the expected value and τ_3/τ_1 at least quadruple.

¹F. J. Lynch and R. E. Holland, Phys. Rev. 114, 825 (1959).

SCATTERING OF HEAVY IONS AND THE HEAVY ION NUCLEUS POTENTIAL

R. H. Siemssen

Invited paper listed by title only: Bull. Am. Phys. Soc. 15, 494 (April 1970)

THE ¹⁸²W(d,p)¹⁸³W REACTION AT 16 MeV

R. H. Siemssen, J. R. Comfort, J. R. Erskine, and J. V. Maher

Bull. Am. Phys. Soc. 15, 552 (April 1970)

Measurements of complete angular distributions of (d,p) reactions on heavy deformed nuclei have previously been restricted to only a few nuclei and to low bombarding energies. The present study was undertaken to search for j dependence as well as for a possible dependence of the angular distributions on the Nilsson orbits into which the neutrons are captured. Data for $E_d = 16$ MeV have been obtained in 5° steps from 10° to 90° with the Argonne split-pole spectrograph and the measurements are being extended to backward angles. Angular distributions have been extracted for approximately 20 states below 2 MeV in excitation.

ENERGY LEVELS IN THE ODD-A Sm ISOTOPES

R. K. Smither, D. J. Buss, and D. L. Bushnell*

Bull. Am. Phys. Soc. 15, 549 (April 1970)

The level schemes of the odd-A Sm isotopes ($A = 145, 149, 151, 153$, and 155) are constructed by using the results of the "neutron average capture" technique developed at Argonne in combination with the data from thermal (n, γ) experiments which make use of Ge(Li) detectors and the Argonne bent-crystal spectrometer. The ground-state J^π values are: $^{145}\text{Sm}, \frac{7}{2}^-$; $^{149}\text{Sm}, \frac{7}{2}^-$; $^{151}\text{Sm}, \frac{3}{2}^-$; $^{153}\text{Sm}, \frac{3}{2}^+$; and $^{155}\text{Sm}, \frac{3}{2}^-$. This removes the uncertainty with regard to the ^{151}Sm and ^{153}Sm isotopes. Of special interest is a new first excited state for ^{155}Sm at 6.6 keV with $J^\pi = \frac{1}{2}^-$ or $\frac{3}{2}^-$. Also, the negative-parity states appear to follow a consistent pattern from isotope to isotope. The neutron binding energies are found to be 6762.7, 5872.5, 5591.7, 5869.1, and 5814.2 keV for the isotopes of mass 145, 149, 151, 153, and 155, respectively.

*Northern Illinois University, DeKalb, Illinois.

POSITIVE-PARITY STATES OF ^{190}Os FROM AVERAGE-RESONANCE-CAPTURE IN $^{189}\text{Os}(n, \gamma)^{190}\text{Os}$

G. E. Thomas and L. M. Bollinger

Bull. Am. Phys. Soc. 15, 549 (April 1970)

The strong high-energy lines in an average-resonance-capture spectrum for a normal osmium sample give the energies of positive-parity states in ^{190}Os , and the γ -ray intensities set limits on the spin J . The energies E in keV and J are given as EJ below, where i means $J = 1$ or 2 and j means $J = 0$ or 3 . The first fourteen positive-parity states of ^{190}Os are $0j$, $187i$, $558i$, $756j$, $911j$, $1114i$, $1383j$, $1435i$, $1545j$, $1569j$, $1616i$, $1676i$, $1688j$, and $1733j$. Three of these states are new. Also, when combined with previous data¹ our

¹M. A. Mariscotti et al., BNL Report No. 11426.

measurements yield the new assignments 1383, 3^+ ; 1545, (3^+) ; 1676, $(2)^+$; 1733, $(3)^+$. Information on states with $E > 1800$ keV is uncertain because of transitions in even-odd nuclides. Preliminary values of neutron separation energies (accurate to 1 keV) are 7987 keV for ^{188}Os and 7790 keV for ^{190}Os .

STUDY OF ^{55}Mn , ^{56}Mn , AND ^{57}Fe WITH THE CORIOLIS-COUPLING MODEL

P. Wasielewski,* J. R. Comfort, F. B. Malik,[†] and W. Scholz[‡]
Bull. Am. Phys. Soc. 15, 478 (April 1970)

Calculations have been performed for ^{55}Mn and ^{57}Fe with a deformed single-particle model which includes Coriolis coupling.¹ The calculations are in very good agreement with the experimental values for excitation energies, magnetic and quadrupole moments, lifetimes, values of $B(E2)$, mixing ratios, and branching ratios. Effective charges were not used. An extension of the model to odd-odd nuclei, with inclusion of an n-p residual interaction, again produced good agreement between calculated and experimental quantities for ^{56}Mn . Comparisons with shell-model calculations will be discussed.

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¹ F. B. Malik and W. Scholz, Phys. Rev. 150, 919 (1966).

MEAN LIFE OF THE THIRD EXCITED STATE IN ^{41}Ca

G. H. Wedberg, G. B. Beard, R. C. Bearse, and R. E. Segel
Bull. Am. Phys. Soc. 15, 601 (April 1970)

The attenuated-Doppler-shift technique has been used to measure the lifetimes of ^{41}Ca excited states populated by the $^{40}\text{Ca}(\text{d}, \text{p})$ reaction. As before,¹ the direction of the recoiling nuclei was defined by coincidence with the outgoing protons. A lifetime of $(9 \pm 2) \times 10^{-13}$ sec was found for the $\frac{3}{2}^-$ first excited state. This is somewhat longer than the previously reported value.² Again² no Doppler shift was found for the 0.52-MeV gamma rays emanating from the $\frac{3}{2}^-$ third excited state. This implies that the lower limit on the lifetime of this state should be raised to $\tau > 4 \times 10^{-12}$ sec. Expressed in the usual single-particle units, the matrix element for the M1 transition to the first excited state is $|M|^2 < 0.1$ and that for the E2 ground-state transition is $|M|^2 < 1.5 \times 10^{-3}$. The transitions are slower than present theories predict.

¹ S. I. Baker and R. E. Segel, Phys. Rev. 170, 1046 (1968).

² P. P. Singh et al., Phys. Rev. 158, 1063 (1967).

Eighteenth Annual Conference on Mass Spectrometry and Allied Topics
San Francisco, California, 14-19 June 1970

PHOTOIONIZATION STUDIES OF F_2 , HF, DF, AND THE XENON FLUORIDES

J. Berkowitz, W. A. Chupka, P. M. Guyon, J. Holloway,
 and R. Spohr

The thresholds for various ionization processes in F_2 and HF have been measured, using a vacuum ultraviolet monochromator to select photon energies from a helium-continuum light source. The thresholds for ion-pair formation and dissociative ionization in F_2 are consistent with a dissociation energy $D_0(F_2) = 1.59 \pm 0.01$ eV. For HF, the corresponding thresholds yield $D_0(HF) = 5.85 \pm 0.01$ eV, consistent with the results of Johns and Barrow. Studies with DF have corroborated the results with HF. Both the F_2 and HF results are in significant disagreement with the conclusions reached in recently published photoionization experiments. In studies with XeF_2 , a weak ion-pair process was observed, corresponding to the formation of $Xe^+ + F^- + F$. Its threshold yields the value $\Delta H_f(XeF_2) = -28.0 \pm 0.5$ kcal/mole. The value of ΔH_f for XeF_2^+ was readily obtained in the same experiment. From the threshold for formation of XeF_2^+ from XeF_4 and XeF_4^+ from XeF_6 , the values $\Delta H_{f_0}(XeF_4) = -57.9 \pm 1.5$ kcal/mole and $\Delta H_{f_0}(XeF_6) = -79 \pm 3$ kcal/mole were then obtained.

DETERMINATION OF ELECTRON AFFINITIES OF SMALL MOLECULES BY ENDOERGIC CHARGE TRANSFER

David Gutman,* William A. Chupka, and Joseph Berkowitz

Thresholds for endoergic charge-transfer reactions of the type $X^- + R \rightarrow X + R^-$, where X^- is a halogen ion, have been measured for various gases R in order to assess their electron affinities. Ion-pair

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formation by photon absorption at threshold wavelengths was used to prepare X^- with small initial kinetic energy. These ions were accelerated by a staircase voltage into a second chamber containing the molecules of interest. Sharp thresholds with tailing consistent with the thermal energy spread of the reactants were generally observed. For several gases, two or more halogen ions were used for the determination of the electron affinities, and the agreement was good in all cases. The preliminary values obtained for the electron affinities are 3.14 eV for F_2 , 2.55 eV for Cl_2 , 2.65 eV for Br_2 , 2.71 eV for I_2 , 0.27 eV for NO, 0.92 eV for O_2 , 2.23 eV for O_3 , and 1.94 eV for NO_2 .

Summer School on Intermediate-Energy PhysicsBanff, Canada, 16—28 August 1970

PRESENT STATUS OF TIME-REVERSAL INVARIANCE

A. Richter*

This is a review of the experimental investigations of time-reversal (T) invariance in the weak, electromagnetic, and strong interactions. The aim is to summarize the results of T experiments at low and high energies, to examine the present status of these experiments and some possibilities for improving them, to discuss their sensitivity, and to mention experiments using the new medium-energy accelerators.

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International Conference on Angular Correlations in Nuclear
Disintegrations

Delft, 17—21 August 1970

COMPUTER-CONTROLLED 70-in. CHAMBER

J. L. Yntema

The Argonne 70-in. chamber was designed to provide a multi-detector system which combines on-line data analysis with computer control over the spatial position of the detector assemblies as well as other experimental parameters. The chamber has four independently moving arms which can be accurately positioned by the computer. Each arm has a detector carriage. The distance from the carriage to the center of the chamber is controlled by the computer to within 0.1 mm. Additional control paths are used for the variation of other parameters such as the target position. Up to twelve detectors have been used simultaneously in singles and in coincidence experiments. The advantages of computer control are the improved bookkeeping, optimization of the experimental conditions, prevention of collisions inside the chamber, and immediate access to the experimental results. The system reduced the need for normalizations and permits a more effective utilization of time since runs with insufficient or excessive statistics can be prevented. The computer has an 8K memory and has access to an external 96K memory, of which 64K are used for data storage and 32K for program storage. A number of charged-particle scattering experiments have been performed with this system which was recently adapted for γ -ray work.

International Conference on Hyperfine Interactions Detected by
Nuclear Radiation

Rehovot, Israel, 6—11 September 1970

HYPERFINE ANOMALIES

G. J. Perlow

The hyperfine anomaly between the ground state and first excited state of ^{193}Ir has been shown to be large ($\sim 6\%$).¹ Measurements in progress indicate a moderately large effect (a preliminary value is 3%) for the corresponding states in ^{191}Ir . Calculations based on several different nuclear models have been made to see whether the results can be explained. Each model predicts a large anomaly—in fact, too large. For just the reason that a small magnetic moment is difficult to calculate when its small value results from a cancellation of large quantities, calculation of the associated large anomalies requires knowledge of the distribution of the nuclear magnetism to an accuracy that is beyond present achievement. The larger magnetic moments and the consequent smaller anomalies can be calculated with greater assurance.

¹G. J. Perlow, W. Henning, D. Olson, and G. L. Goodman, Phys. Rev. Letters 23, 680 (1969).

III. ABSTRACTS OF PAPERS ACCEPTED FOR PUBLICATION

DIATOMIC IONS OF NOBLE GAS FLUORIDES

J. Berkowitz and W. A. Chupka

Chem. Phys. Letters (November 1970)

ArF^+ is formed by $\text{F}_2^+ + \text{Ar}$ and by $\text{Ar}^+ + \text{F}_2$; ArF_2^+ is formed by a weak chemi-ionization process. The first two are exothermic and imply $D_0(\text{ArF}^+) \geq 1.655 \text{ eV}$. Corresponding reactions of F_2^+ with Ne and He were not detected, even at high collision energy.

Λ N TENSOR FORCES FOR SCATTERING AND FOR THE Λ -PARTICLE BINDING IN NUCLEAR MATTER

A. R. Bodmer, D. M. Rote,* and A. L. Mazza*

Phys. Rev. (October 1970)

The effect of Λ N tensor forces on the Λ -particle binding in nuclear matter is studied with the use of second-order perturbation theory and the Brueckner-Bethe reaction-matrix approach in the g -matrix approximation. The g matrix is calculated self-consistently by use of the Kallio-Day version of the reference-spectrum method. The free kinetic energies are assumed for the unoccupied states. One-boson-exchange (OBE) models indicate that the Λ N tensor force is expected to be of short range and moderate strength. For short-range tensor forces the dominant momentum components are very large, and the effects of such forces are only slightly modified by the nuclear medium. On the other hand, if the Λ N tensor forces were of rather long range, they would be quite strongly suppressed in nuclear matter. These features are very clearly exhibited by consideration of the effective nonlocal central potentials that represent the (s -state) effect of tensor forces for nuclear matter and for scattering. The ratio of the (nuclear-matter) expectation values of these two effective potentials is a good measure of the suppression. The expectation value of the effective potential for nuclear matter is just the second-order perturbation-theory energy. Reaction-matrix calculations show that higher-order effects may become quite important for shorter ranges. Such calculations have, in particular, been made for various mixtures of central

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and tensor forces chosen to give a constant s-wave scattering length. Yukawa shapes corresponding to the kaon and one- and two-pion masses were used, as well as "realistic" OBE potentials with a hard core and a tensor component due to kaon exchange (and also approximately due to η exchange). For a particular mixture, the suppression is measured by the reduction in the well depth relative to the depth for a purely central potential which has the same hard core and the same scattering length and effective range as the mixture. For the short-range tensor forces there is rather little suppression even for very strong tensor forces which account for all the triplet scattering. Different assumptions about the d-state interaction have an almost negligible effect on the s-state well depth if the same assumption is made for both scattering and nuclear matter. Similar considerations are made for the effect of tensor forces in the p wave, for which we find very little suppression (≤ 1 MeV). We conclude that if central and short-range tensor forces are chosen to compensate each other for low-energy scattering, they will also compensate each other quite closely for nuclear matter. In particular, for the OBE potentials with strengths consistent with the phenomenological values of the $\Lambda\bar{N}K$ coupling constants, the reduction in the well depth is at most about 4 MeV. The conclusions about the ΛN interaction obtained from a comparison of the calculated and phenomenological well depths are, therefore, effectively unchanged by the presence of a ΛN tensor force. Consequently, in order to bring the two numbers into agreement, it is necessary to invoke a substantial short-range repulsion, a rather weak p-state interaction, and suppression of the ΛN - ΣN coupling and/or repulsive ΛNN three-body forces.

AVERAGE-RESONANCE METHOD OF NEUTRON-CAPTURE γ -RAY SPECTROSCOPY: STATES OF ^{106}Pd , ^{156}Gd , ^{158}Gd , ^{166}Ho , AND ^{168}Er

L. M. Bollinger and G. E. Thomas
Phys. Rev.

The average-resonance method of neutron-capture γ -ray spectroscopy is critically examined by means of measurements on stable isotopes of palladium, gadolinium, holmium, and erbium. A mathematical model of the capture process is developed. This model shows that the intensities of the lines in average-resonance-capture spectra can yield the parities and set narrow limits on the spins of states in almost all nuclides with $A > 100$ if the γ -ray strength function is a smooth function of γ -ray energy and if the random fluctuations in intensity result only from the Porter-Thomas distribution of partial radiation widths. The measurements give extensive data for ^{106}Pd , ^{156}Gd , ^{158}Gd , ^{166}Ho , and ^{168}Er , and some for ^{103}Pd , ^{105}Pd , ^{155}Gd ,

^{157}Gd , ^{165}Er , ^{167}Er , and ^{169}Er . These data are examined for information relating to the mechanisms of radiative capture. All of the data are consistent with the hypothesis that the radiation widths are a smooth function of γ -ray energy and that the random fluctuations in intensity are well described by the Porter-Thomas distribution. The intensities of E1 transitions vary with γ -ray energy more rapidly than E_γ^3 , as expected from a giant-resonance description of the radiative process. The intensity of M1 radiation was measured over a 2-MeV range for ^{106}Pd and ^{168}Er , and the reduced M1 widths for ^{106}Pd form a giant-resonance-like curve that peaks at ~ 7.8 MeV. Ratios of widths for E1 and M1 radiation and for E1 and E2 radiation are obtained for several nuclides. These properties of radiative capture are used to obtain spectroscopic information about final states. The most complete results are for ^{166}Ho , for which 16 rotational bands are identified and interpreted in terms of the collective model. Similar but less extensive data are obtained for ^{156}Gd , ^{158}Gd , and ^{168}Er . The measurements on ^{106}Pd show that the shapes of the observed γ -ray lines may be used to determine the parities of final states.

ROTATIONAL BANDS OF ^{166}Ho

L. M. Bollinger and G. E. Thomas
Phys. Letters B (1970)

Nuclear states of ^{166}Ho were studied by means of the average-resonance-capture method of neutron-capture γ -ray spectroscopy. An exceptionally large number of states were observed and their spins and parities determined. These states form 16 rotational bands that are in generally good agreement with what is expected from the collective model.

LEVEL STRUCTURE OF ^{148}Sm AND ^{150}Sm FROM AVERAGE RESONANCE NEUTRON CAPTURE

D. J. Buss and R. K. Smither
Phys. Rev.

The average-resonance-neutron-capture spectra of $^{147}\text{Sm}(n, \gamma)^{148}\text{Sm}$ and $^{149}\text{Sm}(n, \gamma)^{150}\text{Sm}$ obtained with the Argonne in-pile (n, γ) facility are used to develop and extend the level schemes of ^{148}Sm and ^{150}Sm . In particular, the experiment gives information

about the spin and parity assignments of 33 levels with excitation energies from 0 to 2.7 MeV in ^{148}Sm and 47 levels from 0 to 2.5 MeV in ^{150}Sm . Unique spin and parity assignments are given for almost all the states below 2.2 MeV in both isotopes. In many cases in which previous experiments gave conflicting indications, the new data led to definite spin assignments. The neutron binding energies in ^{148}Sm and ^{150}Sm were found to be 8140.6 ± 1.8 and 7986.4 ± 1.8 keV, respectively, after correction for the energy spectrum of the captured neutrons.

HYPERFINE STRUCTURE OF $^5\text{I}_{8,7}$ ATOMIC STATES OF $^{161,163}\text{Dy}$, AND THE GROUND-STATE NUCLEAR MOMENTS

W. J. Childs

Phys. Rev.

The atomic-beam magnetic-resonance technique has been used to measure the hyperfine structure of the $4f^{10}6s^2\ ^5\text{I}_{8,7}$ atomic states of $^{161,163}\text{Dy}$. Values of the hyperfine-interaction constants A, B, and C, corrected for hyperfine interactions with other states, are given for both atomic states of each isotope. It is found that for the nuclear ground states of $^{161,163}\text{Dy}$: $\mu^{163}/\mu^{161} = -1.400(3)$ and, less accurately, $\mu^{163} = +0.65(6)$ nm, $Q^{163} = +2.51(30)$ b, $\mu^{161} = -0.46(5)$ nm, $Q^{161} = +2.37(28)$ b. The electron g factor g_J is measured for the atomic states $4f^{10}6s^2\ ^5\text{I}_{8,7,6}$ and also for the lowest $J=8$ level of $4f^95d6s^2$ at 7565 cm^{-1} . The lifetime of this level cannot be appreciably less than 2 msec, the transit time for the atom in the apparatus.

$g_{9/2}-d_{5/2}$ INTERACTIONS IN ^{96}Nb AND ^{92}Nb

J. R. Comfort, J. V. Maher, G. C. Morrison, and J. P. Schiffer

Phys. Rev. Letters (10 August 1970)

The reaction $^{96}\text{Zr}(^3\text{He},t)^{96}\text{Nb}$ was studied and six states belonging to the $(\pi g_{9/2})(\nu d_{5/2})^{-1}$ configuration were identified. The energies and spin assignments agree well with those derived by use of the Pandya transformation from the known states of ^{92}Nb belonging to the $(\pi g_{9/2})(\nu d_{5/2})$ configuration.

EVIDENCE FOR A $J^\pi = 8^+$ STATE IN ^{16}O

J. R. Comfort, G. C. Morrison, B. Zeidman, and H. T. Fortune

Phys. Letters (1970)

A 4p-4h state near 20.8 MeV in ^{16}O , populated by the $^{12}\text{C}(^6\text{Li}, d)^{16}\text{O}$ and $^{12}\text{C}(^7\text{Li}, t)^{16}\text{O}$ reactions, is found to have a high spin value. It is suggested to be the $J^\pi = 8^+$ member of the first even-parity rotational band.

PROPERTIES OF ^{55}Mn , ^{56}Mn , AND ^{57}Fe IN THE UNIFIED ROTATIONAL MODELJ. R. Comfort, P. Wasielewski,^{*} F. B. Malik,[†] and W. Scholz[‡]
Nucl. Phys.

A deformed single-particle model which includes the Coriolis coupling is used to calculate the properties of ^{55}Mn and ^{57}Fe . The available experimental data are reviewed and compared with the calculated results. Good agreement is obtained for the energy levels, electromagnetic properties, and stripping spectroscopic factors. An extension of the model to odd-odd nuclei, with inclusion of an n-p residual interaction, also produced good agreement with experimental quantities for ^{56}Mn . Consideration of these results in comparison with shell-model calculations leads to arguments that these nuclei may be statically deformed.

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STUDY OF ENERGY LEVELS OF ^{29}Si D. Dehnhard^{*} and J. L. Yntema

Phys. Rev.

The $^{30}\text{Si}(^3\text{He}, \alpha)^{29}\text{Si}$ reaction was studied by use of the 12-MeV ^3He beam of the Argonne EN tandem Van de Graaff and a

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broad-range magnetic spectrograph. Energy levels of ^{29}Si up to about 10 MeV excitation were observed, and spectra at ten angles were taken. Relative spectroscopic factors were extracted with the aid of distorted-wave calculations. The results were compared with previous neutron-pickup reactions on ^{30}Si and with theoretical predictions which were calculated within the framework of the rotational model.

SHORT-LIVED FISSION ISOMERS FROM NEUTRON STUDIES

A. J. Elwyn and A. T. G. Ferguson*

Nucl. Phys. (1970)

Spontaneously fissioning activities with half-lives of 4–67 nsec have been observed in neutron-induced reactions on isotopes of U and on ^{239}Pu . These activities have been assigned to isomeric states in ^{234}U , ^{235}U , ^{236}U , and ^{240}Pu . In the case of ^{240}Pu , the data are consistent with the existence of two short-lived isomers. The cross sections for isomer production at $E_n \approx 2.2$ MeV have been obtained, but only very approximate values of the isomer ratios have been determined. These tentative values appear to be somewhat larger than isomer ratios found in charged-particle-induced fission. The present data along with the known spontaneous-fission properties of the ground state are consistent with the model of a one-dimensional double-humped fission barrier in which the excitation energy of the isomeric state relative to the ground state is ≤ 2.4 – 3.3 MeV (dependent upon the final nucleus).

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COMMENT ON THE NUMBER OF DEGREES OF FREEDOM IN FLUCTUATION ANALYSIS

H. L. Harney* and A. Richter

Phys. Rev. (August 1970)

Different methods of calculating the number of degrees of freedom N_{eff} in statistical cross-section fluctuations are compared. The underlying physical assumptions of the methods are discussed critically, and numerical examples for N_{eff} are given.

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RADIATIVE DECAY OF $d_{3/2}$ -HOLE STATES

R. E. Holland and F. J. Lynch

Phys. Rev.

Lifetimes were measured for ^{39}K , ^{41}Ca , and ^{43}Ca states formed by promoting a particle from the $d_{3/2}$ shell to the $f_{7/2}$ shell. In ^{43}Ca , this state occurs at 990-keV excitation and has a mean life of 0.12 ± 0.04 nsec. By taking account of the branching ratio we find that the partial mean life for the transition $\frac{3}{2}^+ \rightarrow \frac{7}{2}^-$ is 45 ± 16 nsec, which represents an inhibition of 120 relative to the single-particle estimate. In ^{41}Ca , the hole state occurs at 2010 keV and has a lifetime of 0.8 ± 0.2 nsec. No other branch is observed, so this is the mean life for the $\frac{3}{2}^+ \rightarrow \frac{7}{2}^-$ transition. It is inhibited by a factor 62 relative to the single-particle estimate. In ^{39}K the state occurs at 2820 keV and the mean life for this $\frac{7}{2}^- \rightarrow \frac{3}{2}^+$ transition is less than 0.08 nsec; the inhibition here is less than 18. All of the above rates are consistent with the theoretical model of Kurath and Lawson. From additional data on ^{43}Ca , we find that the partial mean life for the 612-keV $\frac{3}{2}^+ \rightarrow \frac{5}{2}^-$ transition is 1.4 nsec. This is 0.06 times the single-particle value and is not explainable in the scheme of Kurath and Lawson.

STATES IN ^{12}B OBSERVED IN THE SCATTERING OF NEUTRONS BY ^{11}B

R. O. Lane,* C. E. Nelson,* J. L. Adams,* J. E. Monahan,

A. J. Elwyn, F. P. Mooring, and A. Langsdorf, Jr.

Phys. Rev. (December 1970)

The polarization $P(\theta)$ and differential cross section $\sigma(\theta)$ for the scattering of neutrons by ^{11}B have been measured for 0.075 MeV $\leq E_n \leq 2.2$ MeV. Both $\sigma(\theta)$ and $P(\theta)$ are simultaneously fitted reasonably well by R-matrix parameters for broad states in ^{12}B with assignments $2^-(\ell = 0)$ and $4^-(\ell = 2)$ at excitation energies $E_x = 4.37$ and 4.54 MeV, respectively. The 2^- level has not previously been observed, while the 4^- level has previously been assigned to be 3^- . These results, together with a previous 3^- assignment for a state at $E_x = 3.39$ MeV, give experimental evidence for proton-hole neutron-particle shell-model configurations $(1p_{3/2})^{-1}(1d_{5/2})$ and $(1p_{3/2})^{-1}(2s_{1/2})$ in ^{12}B . Shell-model calculations were made with δ -function residual interactions and include configuration mixing of the resulting 2^- states. Work on T=1 states in $^{12}\text{C}^*$ has been compared with the present work.

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SPIN DEPENDENCE IN INELASTIC SCATTERING

J. C. Legg,* D. R. Abraham,* J. L. Yntema, R. C. Bearse,
and H. T. Fortune
Phys. Rev.

The inelastic scattering of deuterons, ^3He , and alpha particles from ^{63}Cu , ^{65}Cu , and ^{67}Zn have been investigated to determine whether spin-dependent effects similar to those observed for protons were observable for these scatterings. The inelastic deuteron scattering shows an effect that is similar to, but stronger than, that seen for proton scattering. The angular distributions for $\frac{1}{2}^-$ states are quite different from those for $\frac{5}{2}^-$ and $\frac{7}{2}^-$ states in ^{63}Cu and ^{65}Cu . The inelastic ^3He scattering exhibits no real structure in its angular distributions for any of the states, so no conclusions may be reached concerning spin-dependent effects for ^3He scattering. The inelastic alpha scattering shows no spin-dependent effect. No definite theoretical explanation for this effect is apparent.

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POLARIZATION PREDICTIONS AND THE QUARK AND PERIPHERAL MODELS

Harry J. Lipkin
Nucl. Phys. (1970)

Inconsistencies and ambiguities in the interpretation of quark-model predictions for decay correlations in resonance production are discussed. A proper relativistic treatment shows which predictions from the nonrelativistic model can be expected to hold at relativistic energies where experimental tests are made. The existence of reasonable peripheral models which lead to the same predictions is pointed out, thus indicating that success of the predictions is not necessarily evidence supporting the quark model.

UNEXPECTED STRONG PAIR CORRELATIONS IN EXCITED 0^+ STATES OF ACTINIDE NUCLEIJ. V. Maher, J. R. Erskine, A. M. Friedman,* J. P. Schiffer,
and R. H. Siemssen

Phys. Rev. Letters (3 August 1970)

The (p,t) reaction has been studied with 17-MeV protons on targets of ^{230}Th , $^{234,236,238}\text{U}$, and $^{242,244}\text{Pu}$. The results indicate unexpectedly strong $\ell=0$ transitions to states at about 900-keV excitation. Their cross sections are approximately 15% of the ground-state transitions; this percentage does not change appreciably with neutron number. This result, together with other available evidence, seems to suggest a simple and rather stable collective mode which has not yet emerged from any theoretical calculations.

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STUDY OF THE EXCITED STATES IN ^3Si BY MEANS OF THE $^3\text{Si}(\alpha, \alpha'\gamma)^3\text{Si}$ REACTIONH. Ohnuma, F. T. Kuchnir, D. S. Gemmell, R. E. Holland,
L. Meyer-Schützmeister, and N. G. Puttaswamy
Nucl. Phys. (1970)

The method II of Litherland and Ferguson was applied to study states in ^3Si by the $^3\text{Si}(\alpha, \alpha'\gamma)^3\text{Si}$ reaction. An annular Si detector placed at 180° to the incident beam and 25 and 30 cm³ Ge(Li) detectors were used for particle and gamma-ray detection, respectively. The results for the first two excited states agree well with previous measurements. The spin assignments 1^+ and 0^+ are suggested for the 3.767- and 3.786-MeV levels, respectively. The 4.808-MeV state has spin and parity 2^+ , the 4.826-MeV state is most likely 2^+ and the 5.948-MeV state is 4^+ . Gamma-ray decay schemes for many states were obtained. No spin 3^- state was strongly excited in the present reaction, and no strong transitions from the 3^- states to the ground state were observed.

NUCLEAR STRUCTURE OF ^{48}Sc FROM THE $^{49}\text{Ti}(\text{d}, ^3\text{He})^{48}\text{Sc}$ REACTION

H. Ohnuma* and J. L. Yntema

Phys. Rev.

The $^{49}\text{Ti}(\text{d}, ^3\text{He})^{48}\text{Sc}$ reaction was studied at 19.45 MeV and 22.4 MeV, and spectroscopic factors were obtained. There are serious discrepancies between the present result and previous work. The present experiment supports a simple picture of the ^{48}Sc nucleus.

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ANGULAR DISTRIBUTIONS OF PHOTOELECTRONS: CONSEQUENCES OF SYMMETRY

Murray Peshkin

Advan. Chem. Phys. (1970)

This article addresses itself to two questions which arise in the design of experimental facilities for measuring the angular distributions of electrons ejected from atoms or molecules by light: What angular distributions are possible? What is gained by using plane or circularly polarized light? These questions have partially been answered previously in the context of calculations involving specific models for the target atoms or molecules. Here they are answered by giving a simple systematic treatment based on symmetry. The only dynamical assumption is the rapid convergence of the multipole expansion of the absorbed light.

It is shown that when the normalized angular distribution of one group of electrons is written in the form

$$I(\theta, \phi) = \sum_{L, M} b_{LM} Y_{LM}(\theta, \phi),$$

the b_{LM} for positive L correspond to particular products of multipole absorption amplitudes. Specifically, the b_{2M} depend only upon pure $E1$ and pure $M1$ absorption, the b_{1M} only upon $E1 \cdot M1$ and $E1 \cdot E2$ interference, and the b_{3M} only upon $E1 \cdot E2$ interference. Circular polarization has no influence upon $I(\theta, \phi)$. Plane polarization modifies the angular distribution in a predictable way, independently of the target atom or molecule. It increases the magnitude of the asymmetry and changes its shape, but plane polarization introduces no dynamical quantity which is not measured with unpolarized light. The group of electrons may be selected by energy or any other scalar criterion.

The conclusions apply independently of the presence or absence of any other particles in the final state.

The joint angular distributions of two ejected electrons are more complicated, and to make sense of them would require additional restrictions from specific dynamical models. However, it is apparent from the general analysis that the dependence of two-electron angular distributions upon polarization is not determined by symmetry alone. In particular, circular polarization can reveal dynamical information which is unavailable with unpolarized or plane-polarized light, even in the pure electric-dipole approximation. Certain interference terms can be seen only with plane polarization, and others only with circular polarization.

It is assumed throughout that the target atoms or molecules are oriented at random.

ISOSPIN NONCONSERVATION IN THE $^{28}\text{Si}(d, \alpha)^{26}\text{Al}(0.23, T=1)$ REACTION

A. Richter, L. Meyer-Schützmeister, J. C. Stoltzfus, and

D. von Ehrenstein

Phys. Rev. (October 1970)

The isospin-nonconserving reaction $^{28}\text{Si}(d, \alpha)^{26}\text{Al}(0.23, T=1)$ has been investigated at deuteron energies between 12 and 17 MeV. This experiment was prompted by Noble's recent proposal that the direct-nuclear part of the cross section in the isospin-violating (d, α) reaction may proceed via an isospin-mixed 2^+ doublet in ^6Li . In the present study we find no evidence for this mechanism; but even at the high bombarding energies, the largest fraction of the isospin-forbidden cross section is due to compound-nucleus processes. This was determined from the strong fluctuations in the excitation functions.

CLOSE SIMILARITIES IN THE EXCITATION FUNCTIONS FROM THE ELASTIC ^{16}O SCATTERING FROM NUCLEI WITH $A \approx 16$

R. H. Siemssen, H. T. Fortune, R. Malmin, A. Richter,

J. W. Tippie,* and P. P. Singh[†]

Phys. Rev. Letters (24 August 1970)

Close similarities are found in the gross structures of the excitation functions from the elastic scattering of ^{16}O from ^{14}N , ^{15}N , and ^{18}O . The picture emerging from the optical-model analysis of these data is that of an interaction potential which is totally absorbing for the low- l partial waves and which is very transparent for the surface partial waves.

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INTENSITY OF K-L_I x-RAY TRANSITIONS

R. K. Smither, M. S. Freedman,* and F. T. Porter*

Phys. Letters A (1970)

The ratio of the intensity of the forbidden K-L_I x-ray transition to that of the K-L_{III} transition was measured to be $(1.8 \pm 0.8) \times 10^{-4}$ in hafnium and $\leq 6 \times 10^{-4}$ in gold. These values are respectively $(47 \pm 20)\%$ and $\leq 75\%$ of the values recently predicted by Rosner and Bhalla.

* Chemistry Division.

RECOILLESS RESONANCE SPECTROSCOPY OF METEORITIC IRON OXIDES

E. L. Sprenkel-Segel

J. Geophys. Res. (10 October 1970)

Recoilless resonance spectra taken at 80°K and 300°K were used to identify oxidation products present in meteorites. Wolf Creek (a completely oxidized iron meteorite) contains (in order of decreasing abundance) αFeOOH , βFeOOH , $\gamma\text{Fe}_2\text{O}_3$, Fe_3O_4 , and γFeOOH . The dark chondrite fragments in the Cumberland Falls achondrite have spectra containing mainly βFeOOH . The unequilibrated ordinary

chondrite Clovis (no. 1) has γFeOOH as the chief oxidation product. Absorption spectra should be recorded at several temperatures in order to avoid ambiguities arising from the presence of superparamagnetic ultrafine particles of iron oxides. A comparison of the Mössbauer spectra of the dark portion of Cumberland Falls with two recent chemical analyses demonstrates that it is not possible to correctly apportion iron among the metal, sulfide, and silicate phases without knowledge of the ferric iron content, which can be determined only by resonance spectroscopy.

IMPROVED ^{121}Sb QUADRUPOLE-MOMENT RATIO FROM MÖSSBAUER STUDIES OF ORGANIC ANTIMONY COMPOUNDS

J. G. Stevens and S. L. Ruby

Phys. Letters (15 June 1970)

Earlier work with Sb_2O_3 gave a value for $R = Q^*/Q$, the ratio of the quadrupole moment of the first excited state to that of the ground state, for ^{121}Sb . The accuracy of this value has been improved by using organic compounds such as $(\text{C}_6\text{H}_5)_3\text{SbCl}_2$, which have larger electric field gradients. The new result is $R = 1.34 \pm 0.01$.

NEW METHOD FOR DISTORTED-WAVE ANALYSIS OF STRIPPING TO UNBOUND STATES

C. M. Vincent and H. T. Fortune

Phys. Rev. (September 1970)

The distorted-wave Born-approximation (DWBA) cross section is discussed for a reaction of the form $A(d, pn)A$ in which n is not observed. We evaluate the slowly convergent oscillating radial integrals by contour integration in the complex radius plane. This avoids the computation of wave functions out to the large distances that the Huby-Mines technique requires. The present technique is also useful for stripping to very weakly bound states. We find that the DWBA angular distribution for stripping to a resonant n state is closely reproduced by using a form factor for the resonant energy of n . The width of the resonance, rather than the spectroscopic factor, is found to be measured by the absolute magnitude of the cross section. The results of calculations with the present method are compared with the results of the Huby-Mines method for the $^{16}\text{O}(d, p)^{17}\text{O}$ reaction leading to the resonant 5.08-MeV state of ^{17}O .

ISOBARIC ANALOG RESONANCES FROM PROTON SCATTERING ON THE BARIUM ISOTOPES

N. Williams, G. C. Morrison, J. A. Nolen, Jr., Z. Vager,
and D. von Ehrenstein

Phys. Rev. (October 1970)

With barium isotopes of mass 130, 132, 134, 136, and 138 as targets, proton elastic-scattering excitation functions have been obtained at several angles. In the proton energy range 7.0–12.0 MeV, we observed several resonances which correspond to isobaric analogs of the low-lying states of the target-plus-neutron systems. The resonance data have been analyzed to extract proton elastic widths, total widths, and resonance energies. Spectroscopic factors have been extracted by comparing the measured proton elastic widths with the single-particle widths calculated on the basis of a shell-model description of the analog state. The spectroscopic factors so determined are compared with those from the Ba(d,p) reaction to the parent analog states. The variation of single-particle widths with the parameters of the bound-state neutron well has been investigated. From the analog resonance energies and the Q values for the parent states in Ba(d,p) reactions, the Coulomb shifts of the principal resonances have been found.

SIMPLE MYLAR WINDOW HELIUM CRYOSTAT FOR MÖSSBAUER MEASUREMENTS

B. J. Zabransky and S. L. Ruby

Rev. Sci. Instr. (September 1970)

The frequent demands for large solid angle, low temperatures, and high transmission in Mössbauer experiments increase the cost and complexity of helium cryostats. A glass cryostat has been constructed that meets these requirements with the simultaneous advantages of low cost and easy construction. A commercial cryostat was modified to accept a 0.005-in. -thick Mylar window bonded to the bottom of the helium container and to the outer vacuum shroud. It gives a transmission $I/I_0 = 0.89$ at 14 keV, its holding time is nearly 4 days on a 3-liter filling, and no window failures have occurred during 19 months of service. The cryostat is now available commercially.

$^{10}\text{B}(\alpha, {}^6\text{Li})^8\text{Be}$ REACTION AT 46 MeV AND THE CONFIGURATION OF
THE ^{10}B GROUND STATE

B. Zeidman, H. T. Fortune, and A. Richter
Phys. Rev. C

Differential cross sections for the reactions $^{10}\text{B}(\alpha, {}^6\text{Li})^8\text{Be}_{g.s.}$ and $^{10}\text{B}(\alpha, {}^6\text{Li})^8\text{Be}_{2.9}$ have been measured in the angular range from 9° to 25° (laboratory system) in 1° steps at $E_\alpha = 46$ MeV. The shapes of the angular distributions are typical of a direct reaction, and the pickup processes are analyzed in distorted-wave approximations on the basis of an extreme cluster model, i. e., on the assumption that a deuteron is picked up from the target nucleus ^{10}B . Calculations using proper two-particle form factors are also performed, and the results agree with the former method. From the ratio of the experimental to the theoretical cross section, a spectroscopic factor (^8Be -core-plus-deuteron-cluster parentage) is obtained and compared with two-particle fractional-parentage coefficients calculated in intermediate coupling.

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STUDY OF THE LOW-LYING $T=\frac{3}{2}$ STATES IN Na^{21}

R. C. Bearse, J. C. Legg,* G. C. Morrison, and R. E. Segel
Phys. Rev. C1(2), 608-612 (February 1970)

ROTATIONAL BANDS OF ^{166}Ho

L. M. Bollinger and G. E. Thomas
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SIMPLE TECHNIQUE FOR PRECISE DETERMINATIONS OF COUNTING LOSSES IN NUCLEAR PULSE-PROCESSING SYSTEMS

H. H. Bolotin, M. G. Strauss (Electronics), and D. A. McClure
Nucl. Instr. Methods 83(1), 1-12 (1970)

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Phys. Rev. C1, 795-803 (March 1970)

HYPERFINE STRUCTURE OF MANY ATOMIC LEVELS OF Tb^{159} AND THE Tb^{159} NUCLEAR ELECTRIC-QUADRUPOLE MOMENT

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* Kansas State University, Manhattan, Kansas.

[†] Florida State University, Tallahassee, Florida.

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EVIDENCE FOR A $J^\pi = 8^+$ STATE IN ^{16}O

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ISOMERIC STATES IN THE REGION $Z > 50$, $N < 82$ PRODUCED IN ($^{12}C, xn$) REACTIONS

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* A. E. R. E., Harwell, Berks., England.

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A. J. Elwyn and A. T. G. Ferguson*

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* A. E. R. E., Harwell, Berks., England.

† Max-Planck-Institut für Kernphysik, Heidelberg, Germany.

‡ Illinois Institute of Technology, Chicago, Illinois.

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J. E. Monahan and R. M. Thaler*
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* Case Western Reserve University, Cleveland, Ohio.

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INTENSITY OF K-L_I x-RAY TRANSITIONS

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*University of Illinois at Chicago Circle, Chicago, Illinois.

†Indiana University, Bloomington, Indiana.

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G. K. Shenoy (Solid State Science) and S. L. Ruby

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Li-INDUCED REACTIONS ON ^{12}C

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SEARCH FOR ISOMERIC STATES IN THE REGION $Z > 50$,
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AMBIGUITIES IN THE IMAGINARY PART OF THE HEAVY-ION
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J. V. Maher, R. H. Siemssen, M. Sachs,[†] A. Weidinger,[†]
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ELASTIC SCATTERING OF ^6Li ON ^6Li

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* A. E. R. E., Harwell, Berks., England.

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R. H. Siemssen, H. T. Fortune, A. Richter, and
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COMPUTER-CONTROLLED MULTIPLE-DETECTOR ARRAY
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* Kansas State University, Manhattan, Kansas.

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NEW DIRECTIONS IN NUCLEAR SPECTROSCOPY (Panel Discussion)

D. H. Wilkinson (Chairman),* G. E. Brown,[†] W.

Greiner,[‡] L. Grodzins,[§] A. E. Litherland,^{||} H. Palevsky,[¶]
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A. Richter, J. R. Comfort, and J. P. Schiffer
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THE (He^3, t) REACTION IN THE $A \approx 90$ REGION

J. P. Schiffer

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* Northern Illinois University, DeKalb, Illinois.

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S. L. Hausladen,[†] R. O. Lane,[†] J. E. Monahan, A. J. Elwyn, F. P. Mooring, and A. Langsdorf, Jr.

Bull. Am. Phys. Soc. 15, 567 (April 1970)

PROTON SCATTERING ON ^{96}Zr THROUGH ISOBARIC ANALOG RESONANCES

R. R. Jones,[‡] C. Fred Moore,[‡] P. Dyer,[§] N. Williams, || and G. C. Morrison

Bull. Am. Phys. Soc. 15, 626 (April 1970)

THE $\text{Mg}^{24,26}(\text{p},\alpha)\text{Na}^{21,23}$ REACTIONS AT 35 MeV

E. Kashy,^{*} W. Pickles,^{*} G. C. Morrison, and R. C. Barse

Bull. Am. Phys. Soc. 15, 544 (April 1970)

$\text{Sr}^{86}(\text{He}^3,\text{d})\text{Y}^{87}$ REACTION AT 20 MeV

J. V. Maher, J. R. Comfort, and G. C. Morrison

Bull. Am. Phys. Soc. 15, 551 (April 1970)

ANGULAR DISTRIBUTION OF RADIATION FROM PROTON CAPTURE BY THE CHLORINE ISOTOPES

L. Meyer-Schützmeister, D. S. Gemmell, N. G. Puttaswamy, H. T. Fortune, J. V. Maher, E. L.

Sprenkel-Segel, R. C. Barse, and R. E. Segel

Bull. Am. Phys. Soc. 15, 566 (April 1970)

* Michigan State University, East Lansing, Michigan.

† Ohio University, Athens, Ohio.

‡ University of Texas, Austin, Texas.

§ California Institute of Technology, Pasadena, California.

|| Rutgers University, New Brunswick, New Jersey.

APS, Washington, D.C. (cont'd.)

$\text{Zr}^{96}(\text{He}^3, t)\text{Nb}^{96}$ REACTION AT 21 MeV

G. C. Morrison, J. R. Comfort, J. V. Maher, and
J. P. Schiffer

Bull. Am. Phys. Soc. 15, 574 (April 1970)

POLARIZATION AND DIFFERENTIAL CROSS SECTIONS FOR
SCATTERING OF NEUTRONS FROM ^{11}B

C. E. Nelson,* R. O. Lane,* J. L. Adams,* J. E.
Monahan, A. J. Elwyn, F. P. Mooring, and A.
Langsdorf, Jr.

Bull. Am. Phys. Soc. 15, 567 (April 1970)

HIGH-LYING NEUTRON-HOLE STATES POPULATED IN THE
REACTION $^{13}\text{C}(p, d)^{12}\text{C}^*$ AT 63 MeV

L. J. Parish,† A. Brown,† K. A. Eberhard,† A. Richter,
and W. v. Witsch‡

Bull. Am. Phys. Soc. 15, 520 (April 1970)

THE $^{48}\text{Ca}(^3\text{He}, t)^{48}\text{Sc}$ REACTION AT 23 MeV

A. Richter, J. R. Comfort, and J. P. Schiffer

Bull. Am. Phys. Soc. 15, 594 (April 1970)

VIBRATION AMPLITUDES IN THE MOLECULAR CRYSTAL
 $\text{Sn}(\text{CH}_3)_4$

S. L. Ruby, I. Pelah (Solid State Science), and J. E.
Robinson (Solid State Science)

Bull. Am. Phys. Soc. 15, 605 (April 1970)

EXCITED 0^+ STATES IN THE (p, t) REACTION ON Pt, W,
AND U ISOTOPES

J. P. Schiffer, J. V. Maher, J. R. Erskine, A. Friedman
(Chemistry), and R. H. Siemssen

Bull. Am. Phys. Soc. 15, 528 (April 1970)

MEAN LIVES OF THE SECOND AND THIRD EXCITED STATES
IN ^{40}K

R. E. Segel, N. G. Puttaswamy, N. Williams, G. H.
Wedberg, and G. B. Beard

Bull. Am. Phys. Soc. 15, 600-601 (April 1970)

* Ohio University, Athens, Ohio.

† Florida State University, Tallahassee, Florida.

‡ Rice University, Houston, Texas.

APS, Washington, D.C. (cont'd.)

THE $^{182}\text{W}(\text{d},\text{p})^{183}\text{W}$ REACTION AT 16 MeV

R. H. Siemssen, J. R. Comfort, J. R. Erskine, and
J. V. Maher

Bull. Am. Phys. Soc. 15, 552 (April 1970)

ENERGY LEVELS IN THE ODD-A Sm ISOTOPES

R. K. Smither, D. J. Buss, and D. L. Bushnell*

Bull. Am. Phys. Soc. 15, 549 (April 1970)

POSITIVE-PARITY STATES OF ^{190}Os FROM AVERAGE-
RESONANCE-CAPTURE IN $^{189}\text{Os}(\text{n},\gamma)^{190}\text{Os}$

G. E. Thomas and L. M. Bollinger

Bull. Am. Phys. Soc. 15, 549 (April 1970)

STUDY OF Mn^{55} , Mn^{56} , AND Fe^{57} WITH THE CORIOLIS-
COUPLING MODEL

P. Wasielewski,[†] J. R. Comfort, F. B. Malik,[‡] and
W. Scholz[§]

Bull. Am. Phys. Soc. 15, 478 (April 1970)

MEAN LIFE OF THE THIRD EXCITED STATE IN ^{41}Ca

G. H. Wedberg, G. B. Beard, R. C. Bearse, and
R. E. Segel

Bull. Am. Phys. Soc. 15, 601 (April 1970)

PHYSICS DIVISION INFORMAL REPORTS

MANUAL OF DATA-ANALYSIS PROGRAMS FOR CHARGED-PARTICLE
REACTIONS

J. R. Comfort

Physics Division Informal Report PHY-1970B (August 1970)

THE ARGONNE (He^3, t) SYMPOSIUM, 25 JANUARY 1970

arranged by J. P. Schiffer

Physics Division Informal Report PHY-1970A (January
1970)

* Northern Illinois University, DeKalb, Illinois.

† Yale University, New Haven, Connecticut.

‡ Indiana University, Bloomington, Indiana.

§ University of Pennsylvania, Philadelphia. Pennsylvania.

STUDENT REPORTS

ANALYSIS OF Ge(Li) DETECTION SYSTEM PEAK SHAPES

John Bellatti

CSUI-ANL student report to Illinois College, Jacksonville,
Illinois (Spring 1970)

MULTI-WIRE PROPORTIONAL COUNTERS WITH WIRES AT ALTERNATING POSITIVE AND NEGATIVE VOLTAGE

G. G. Campbell

CSUI-ANL student report to Thiel College (Spring 1970)

A STUDY OF NUCLEAR STRUCTURE IN THE $A = 90$ REGION

James W. Connelley

CSUI-ANL student report to The University of Pittsburgh
(Spring 1970)

GAMMA-RAY SPECTROSCOPY WITH A Ge(Li) DETECTOR—AN EFFICIENCY DETERMINATION

D. A. Dolejsi

Summer Student Trainee report to Wisconsin State
University, Platteville, Wisconsin (Summer 1970)

PARITY BREAKDOWN IN A NUCLEAR DECAY MODE

David Lieberworth

Summer Student Trainee report to Northwestern
University (Summer 1970)

DETERMINATION OF NUCLEAR ENERGY LEVELS BY STATISTICAL AND COMPUTER METHODS

Thomas E. Main

ACM student report to Knox College (Spring 1970)

RADIOFREQUENCY PLASMAS AND TROUBLE-SHOOTING THE APPARATUS USED TO MEASURE THEIR COMPLEX IMPEDANCE

Edward P. Mikkelsen

Summer Student Trainee report to College of Wooster,
Wooster, Ohio (Summer 1970)

COMPLEX IMPEDANCE OF RADIOFREQUENCY PLASMAS

Richard W. Nopper, Jr.

CSUI-ANL student report to John Carroll University,
Cleveland, Ohio (Spring 1970)

OPTICAL-MODEL ANALYSES OF HEAVY-ION ELASTIC-SCATTERING
EXPERIMENTS

Thaddeus Orzechowski

Summer Student Trainee report to Marquette University
(Summer 1970)

METHODS OF DETERMINING GAMMA-RAY ENERGIES USING A
Ge(Li) DETECTOR

Anthony E. Thomas

Summer Student Trainee report to Texas Southern
University (Summer 1970)

ENERGY ANALYSIS WITH A SPHERICAL CAPACITOR

Larry Zobel

ACM student report to St. Olaf College (Spring 1970)

OPTICAL MODEL ANALYSIS OF HEAVY-ION FLUENCE AT BAWO

EXPERIMENTAL
THIS IS A RESEARCH
SUMMIT AND A RESEARCH
(SUMMIT 1977)

ARTICLES OF THE JOURNAL OF DAMMA-PAI
(GAM) DETECTOR

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V. PERSONNEL CHANGES IN THE ANL PHYSICS DIVISION

NEW MEMBERS OF THE DIVISION

Visiting Scientists

Dr. Hans-Joachim Körner, Technische Universität München, München, Germany. Nuclear spectroscopy at the tandem Van de Graaff accelerator. Came to Argonne on 3 September 1970.

Dr. Franca T. Kuchnir, University of Illinois, Chicago Circle Campus. Neutron-physics experiments at the Dynamitron. Returned to Argonne on 1 July 1970.

Visiting Scientists (Summer)

Dr. Mitsuji Kawai, Tokyo Institute of Technology, Tokyo, Japan. Theory of direct nuclear reactions, especially (d,p) stripping reactions and ($^3\text{He},t$) charge-exchange reactions. Came to Argonne on 1 May 1970.

Dr. Harry J. Lipkin, Weizmann Institute of Science, Rehovot, Israel. Theoretical high-energy physics, duality, quarks, hypernuclear analog states, etc. Returned to Argonne on 23 June 1970.

Research Associate

Dr. Udo Strohbusch, University of Freiburg, Freiburg, Germany.

Investigation of charged-particle-induced reactions at the tandem. Came to Argonne on 23 September 1970.

Research Associate (Summer)

Mr. Linden A. Davis, Jr., University of Pennsylvania, Philadelphia,

Pennsylvania. Analysis of data on charged-particle reactions. Returned to Argonne on 12 May 1970.

Postdoctorals

Dr. Yshai Avishai. N-body scattering. Came to Argonne on 10 September 1970.

Dr. Lawrence R. Greenwood. Design and testing of proportional counters for the magnetic spectrograph; search for the parity-violating α decay of the 8.87-MeV level in ^{16}N ; study of ($^3\text{He}, d$) and ($^3\text{He}, p$) reactions on ^{58}Fe and ^{41}Ca . Came to Argonne on 1 September 1970.

Dr. Kenji Katori. Charged-particle experiments; study of target-spin-dependent interactions in nuclear scattering and reactions. Came to Argonne on 26 August 1970.

Dr. Franklin J. D. Serduke. Off-shell effects in three-nucleon systems; influence of the tensor force on nuclear saturation properties. Came to Argonne on 18 September 1970.

Resident Associates

Dr. Edward Strait, Macalester College, St. Paul, Minnesota.

Threshold photoneutron studies. (ACM-ANL supervisor, ACEA, University-AEC Laboratory Cooperation; Faculty Research Participation Program.) Came to Argonne on 1 July 1970.

Dr. William W. True, University of California, Davis, California.

Theory of nuclear structure. (ACEA affiliate, Faculty Research Participation Program.) Came to Argonne on 1 September 1970.

Resident Associates (Summer)

Dr. David L. Bushnell, Northern Illinois University, DeKalb, Illinois.

Deducing the level scheme of ^{180}Hf from data obtained with the bent-crystal and Ge(Li) spectrometers; modifications of the bent-crystal spectrometer. (ACEA affiliate, Summer Faculty Research Participation Program.) Returned to Argonne on 1 June 1970.

Dr. Mazhar Hasan, Northern Illinois University, DeKalb, Illinois.

Slab-model theory of impedance of radio-frequency gas discharges. (ACEA affiliate, Summer Faculty Research Participation Program.) Returned to Argonne on 8 July 1970.

Dr. Stephan J. Krieger, University of Illinois at Chicago Circle,
Chicago, Illinois. Single-particle energy levels in heavy
nuclei. (ACEA affiliate, Summer Faculty Research
Participation Program.) Came to Argonne on 8 June 1970.

Dr. Hugh Siefken, Greenville College, Greenville, Illinois. Analysis of
d- γ coincidences in the ($^3\text{He}, d\gamma$) reaction on ^{45}Sc .
(ACEA affiliate, Summer Faculty Research Participation
Program.) Came to Argonne on 4 June 1970.

Dr. John G. Stevens, University of North Carolina at Asheville, North
Carolina. Working towards completion of Mössbauer
Effect Data Index (1969); Mössbauer studies of frozen
aqueous solutions. (ACEA affiliate, Summer Faculty
Research Participation Program.) Returned to Argonne
on 8 June 1970.

Graduate Student Appointments (Thesis Parts)

Mr. Yue-Kong Au, Northwestern University, Evanston, Illinois.
Working with R. E. Segel on an experiment to determine
neutrino production on the sun. (ACEA affiliate, Resident
Associate, Thesis Parts Guest Program.) Came to
Argonne on 6 August 1970.

Mr. Paul J. Dawson, Illinois Institute of Technology, Chicago, Illinois.
Working with R. E. Segel on an experiment to determine
neutrino production on the sun. (ACEA affiliate, Resident
Associate, Thesis Parts Guest Program.) Returned to
Argonne on 27 July 1970.

Mr. Victor Fong, Michigan State University, East Lansing, Michigan.

Working with W. A. Chupka on molecular structure determination by photoionization method. (ACEA affiliate, Resident Student Associate, Thesis Parts.) Came to Argonne on 1 April 1970 for a period of six months.

Mr. Charles L. Johnson, Physics Department, Ohio University, Athens,

Ohio. Working with S. L. Ruby on the use of computer procedures for analyzing Mössbauer data. (ACEA affiliate, Thesis Parts, Thesis Appointee.) At Argonne from 21 to 23 July 1970.

Mr. James H. Sternbergh, Northwestern University, Evanston, Illinois.

Working with R. E. Segel on nuclear structure experiments involving light nuclei. (ACEA affiliate, Resident Associate, Thesis Parts Guest.) Came to Argonne on 10 August 1970.

Resident Student Associates (Thesis)

Mr. Narayanaswami Anantaraman, graduate student, University of

Chicago, Chicago, Illinois. Working with J. P. Schiffer on experimental study and analysis of systems consisting of a closed shell + two nucleons (holes). Came to Argonne on 15 June 1970.

Mr. John F. Lemming, graduate student, Ohio University, Athens,

Ohio. Working with A. J. Elwyn on polarization of neutrons decaying from isobaric-analog resonances formed by bombarding with protons. Came to Argonne on 18 September 1970.

AUA-ANL Predoctoral Fellowship

Mr. William Corwin, graduate student, Illinois Institute of Technology, Chicago, Illinois. Working with R. E. Segel on giant-resonance studies. Came to Argonne on 20 July 1970.

Guest Graduate Student (Summer)

Rev. Charles F. Shelby, graduate student, DePaul University, Chicago, Illinois. Working with A. J. Hatch on rf confinement of low-density plasmas. Came to Argonne on 15 June 1970.

CSUI-ANL Honor Students

Miss Michelle Fluckey, Colorado College, Colorado Springs, Colorado. Working with L. Meyer-Schützmeister on measurements of angular distributions in the $^{54}\text{Fe}(^3\text{He}, p)$ reaction. Came to Argonne on 8 September 1970.

Mr. William R. Fuller, Trinity College, Hartford, Connecticut. Working with R. H. Siemssen on parameterization in phase-shift analysis of heavy-ion scattering. Came to Argonne on 8 September 1970.

Mr. John C. Hayward, Jr., Wheaton College, Wheaton, Illinois. Working with T. H. Braid on multi-wire proportional counters for particle location. Came to Argonne on 8 September 1970.

Mr. Thomas R. Moenter, St. Olaf College, Northfield, Minnesota.

Working with G. J. Perlow on studies with the Mössbauer effect. Came to Argonne on 8 September 1970.

Mr. Stephen H. Patterson, Ottawa University, Ottawa, Kansas.

Working with H. H. Bolotin on computer codes for analysis of complex γ -ray spectra; coincidence studies of neutron-capture γ rays. Came to Argonne on 8 September 1970.

Mr. James D. Severa, Creighton University, Omaha, Nebraska.

Working with W. A. Chupka on photoionization of gases. Came to Argonne on 8 September 1970.

Summer Student Training Program

Mr. Duane A. Dolejsi, Wisconsin State University, Platteville, Wisconsin.

Working with H. H. Bolotin on gamma-ray spectroscopy with a Ge(Li) detector. Came to Argonne on 14 June 1970.

Mr. Henry Halperin, Purdue University, Lafayette, Indiana. Working

with J. Berkowitz on photoelectron spectroscopy of high-temperature vapors by use of a cylindrical-mirror analyzer. Came to Argonne on 14 June 1970.

Mr. David Lieberworth, Northwestern University, Evanston, Illinois.

Working with R. E. Segel on parity breakdown in a nuclear decay mode. Came to Argonne on 14 June 1970.

Mr. Gerard H. Marks, Manhattan College, Bronx, New York. Working with S. L. Ruby on metastable phases in the ferrous chloride hydrates. Came to Argonne on 14 June 1970.

Mr. Edward P. Mikkelsen, College of Wooster, Wooster, Ohio. Working with A. J. Hatch on radiofrequency plasmas and on the apparatus used to measure the complex impedance of these discharges. Came to Argonne on 14 June 1970.

Mr. Thaddeus Orzechowski, Marquette University, Milwaukee, Wisconsin. Working with R. H. Siemssen on analyses of heavy-ion elastic-scattering experiments. Came to Argonne on 14 June 1970.

Miss Anne Ritger, Trinity College, Washington, D. C. Working with L. Meyer-Schützmeister on measurement of angular distributions in the $^{56}\text{Fe}({}^3\text{He}, p)$ reaction. Came to Argonne on 14 June 1970.

Mr. Anthony E. Thomas, Texas Southern University. Working with S. B. Burson on methods of determining gamma-ray energies with a Ge(Li) detector. Came to Argonne on 14 June 1970.

Scientific Assistant

Mr. Neil C. Barringer joined the Physics Division on 21 September 1970 to work with M. Kaminsky.

Technicians

Mr. Ardell Brown joined the Physics Division on 21 September 1970 to work with T. H. Braid.

Mr. Norman N. Sobol transferred from the Applied Mathematics Division to the Physics Division on 16 April 1970 to work with R. K. Smither and J. R. Erskine.

LEAVES OF ABSENCE

Dr. Arnold R. Bodmer left ANL in August 1970 to go to the Nuclear Physics Department, Oxford University, Oxford, England. He plans to return to Argonne in August 1971.

Dr. Leonard S. Goodman left ANL in August 1970 to go to Laboratoire Aimé Cotton, C.N.R.S. Campus d'Orsay, Orsay, France. He plans to return to Argonne in August 1971.

PART-TIME APPOINTMENTS

Dr. David C. Hess became associate editor for The Journal of Applied Physics and Applied Physics Letters on 20 April 1970.

Dr. Richard S. Preston became a half-time Professor of Physics at Northern Illinois University, DeKalb, Illinois, on 8 September 1970.

DEPARTURES

Dr. George B. Beard, resident associate (ACEA, Faculty Research Participation Program) from Wayne State University has been on the staff of the ANL Physics Division since 14 July 1969. He has worked on attenuated-Doppler-shift lifetime measurements and Coulomb-excitation studies. He terminated at ANL on 18 September 1970 to return to Wayne State University, Detroit, Michigan.

Dr. Joseph R. Comfort, postdoctoral appointee, has been on the staff of the ANL Physics Division since 12 September 1968. He has worked on many projects, all related to nuclear structure research with the Tandem Van de Graaff accelerator; deformed model calculations near ^{56}Mn ; correlations between (d,p) and (n, γ) reactions; computer programs for data analysis. He terminated at ANL on 1 September 1970 to go to Princeton University, Princeton, New Jersey.

Mr. Hsiang Fan, resident student associate from the University of Chicago has been on the staff of the ANL Physics Division since 12 January 1970. He has worked on scanning and data analysis. He terminated at ANL on 1 May 1970 to return to the University of Chicago, Chicago, Illinois.

Dr. James V. Maher, Jr., postdoctoral appointee, has been on the staff of the ANL Physics Division since 19 November 1968. He has worked on parity violation in nuclear reactions; $^{11}\text{B}(\text{d},\text{p})$; (p,t) reaction on actinide targets; ($^3\text{He},\text{t}$) reaction on ^{96}Zr ; (d, α) reaction in Zr region; $^{10}\text{B}(^3\text{He},\text{d})^{11}\text{C}$; single-nucleon transfers on N = 14

nuclei; $^{86}\text{Sr}(^3\text{He},\text{d})^{87}\text{Y}$. He terminated at ANL on 28 August 1970 to go to the University of Pittsburgh, Pittsburgh, Pennsylvania.

Dr. Harry G. Miller, resident associate (ACEA affiliate, Faculty Research Participation Program) from Defiance College has been on the staff of the ANL Physics Division since 3 September 1969. He has worked on thermal-neutron beam facility for measurement of internal-conversion coefficients of capture-gamma transitions. He terminated at ANL on 31 July 1970 to return to Defiance College, Defiance, Ohio.

Mr. Jeffrey M. Moller, resident student associate from the University of Chicago, Chicago, Illinois, has been on the staff of the ANL Physics Division since 1 November 1969. He has worked on analysis of data on charged-particle reactions. He terminated at ANL on 1 June 1970.

Mr. Richard F. Rapids, resident student associate from the University of Chicago, Chicago, Illinois, has been on the staff of the ANL Physics Division since 2 October 1968. He has worked on analysis of data on charged-particle reactions. He terminated at ANL on 1 May 1970.

Dr. William J. Romo, postdoctoral appointee, has been on the staff of the ANL Physics Division since 3 June 1968. He has worked on the continuum shell model; high-energy inelastic scattering from a ^6Li target. He terminated at ANL on 31 July 1970 to go to Carleton University, Ottawa, Canada.

Mr. Elliot S. Silber, scientific assistant, has been in the Physics Division since 10 July 1967. He terminated at ANL on 24 April 1970.

Dr. W. Gene Stoppenhagen, postdoctoral appointee, has been on the staff of the ANL Physics Division since 14 June 1968. He has worked on the installation of the Dynamitron and on its pulsed ion source; fast-neutron physics; time-of-flight spectrometer; polarized ion source at the Tandem; heavy-ion experiments at the Tandem. He terminated at ANL on 18 August 1970 to go to Ohio University, Lancaster, Ohio.

Dr. C. Martin Vincent, visiting scientist, has been on the staff of the ANL Physics Division since 18 September 1967. He has worked on nuclear-matter theory; theory of stripping to unbound states; SPEAKEASY. He terminated at ANL on 21 August 1970 to go to the University of Pittsburgh, Pittsburgh, Pennsylvania.

Mr. Ralph Waldhauser, scientific technician, has been in the Physics Division since 26 April 1963. He terminated at ANL on 24 July 1970.

Transfer

Miss Christine Paul, receptionist, has been in the Physics Division since 16 September 1968. She transferred to Payroll in the Accounting Department on 13 April 1970.

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